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# Canadian Aeronautical Journal

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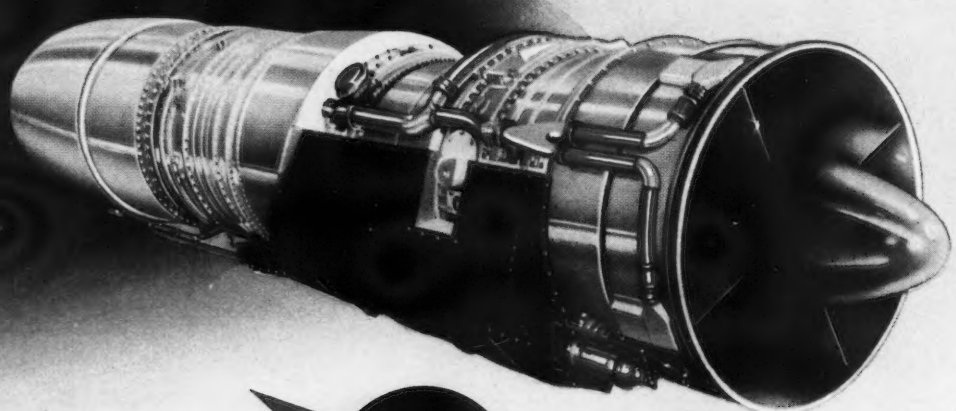

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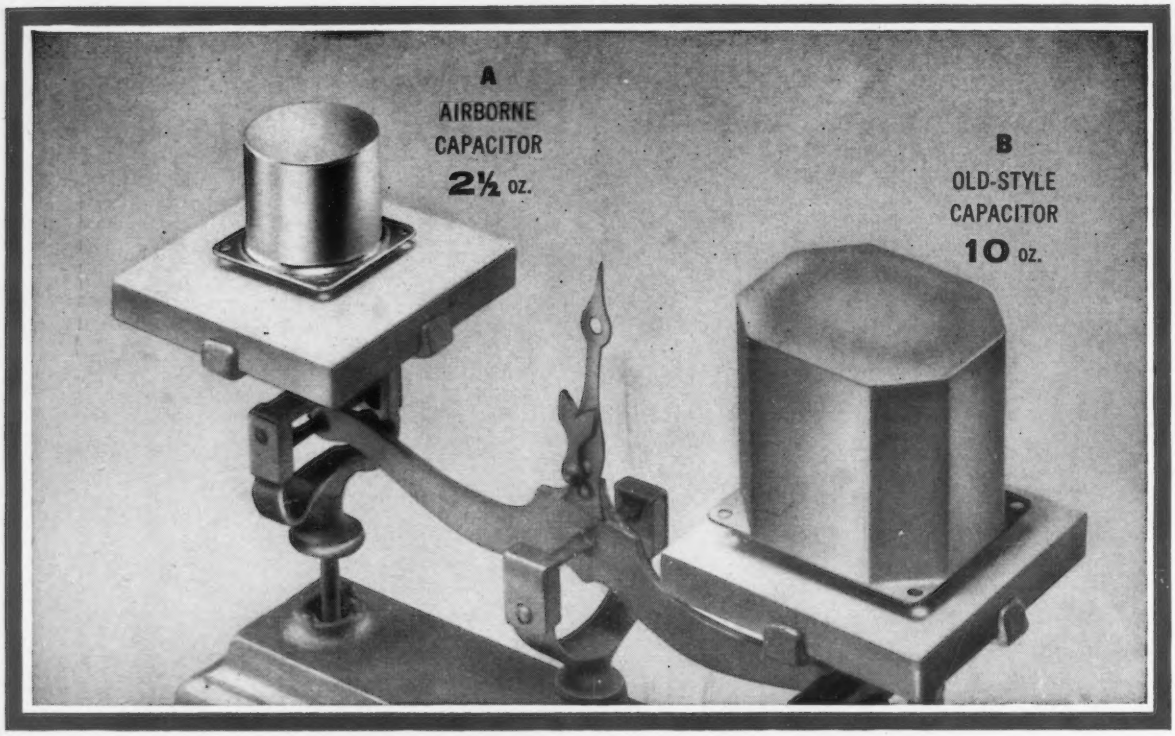


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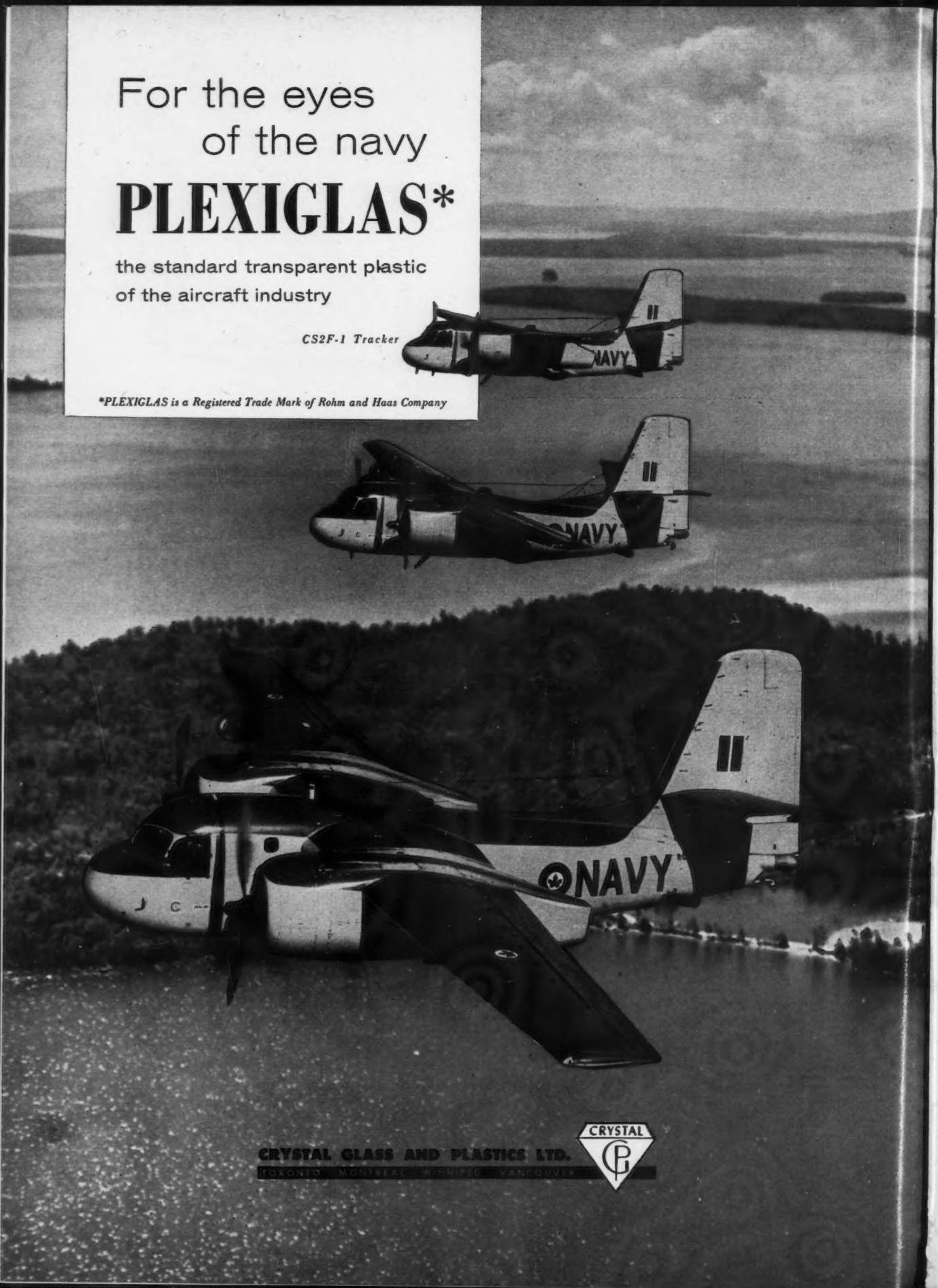
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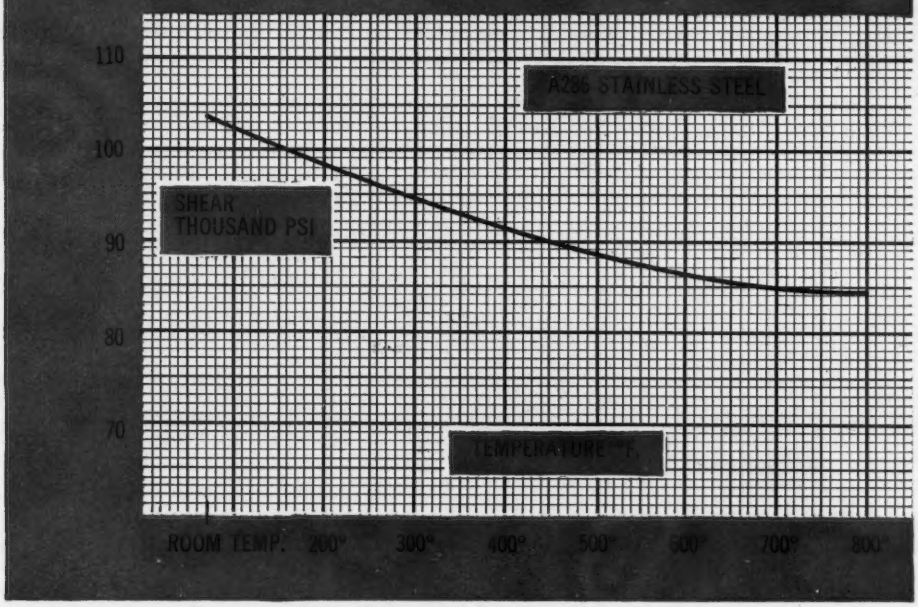


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# EDITORIAL

## ONE MAN'S MEAT CAN BE EVERYBODY'S MEETING

WHY is the C.A.I.? That's simple. It says right on page one that the C.A.I. exists to advance the art and science of aeronautics in Canada. That sounds pretty good and it seems to put the emphasis on the technical and leave the commercial to other organizations. But just how do we do this?

One of our principal activities is the holding of meetings to which we hope to get "a good turnout". A large attendance at meetings is, of course, a good thing since people often will talk to each other on problems of mutual interest. With luck, this might advance the art a notch or two.

Now there is a lurking fear that if there is to be a speaker who is to deliver a technical paper this will prevent a good turnout, thereby discouraging (a) the members and (b) the speaker, not to mention the embarrassment of the Chairman. There are some who say that having a speaker is all right provided he talks in a nice general way so as to appeal to all possible grades of membership including guests. Using the constant volume principle, we can see that such treatment must have a depth inversely proportional to the breadth of coverage. Like dew on a meadow.

It seems to us that if we are really going to advance the art, we must present top-grade technical papers. Surely our members will be ready to come out and take some mental exercise in following a good technical presentation. Our members are stimulated by new ideas and new information. Learning is a perpetual thing.

It is true that every such speaker will not have a membership-wide appeal. However, each meeting can be devoted to a different technical area and throughout the year most members will have had some real increase in knowledge in aeronautics.

C.A.I. meetings are not meant to be light entertainment. This is not to say that the whole evening need be conducted in sepulchral academic gloom. As far as we have observed, the Canadian aeronautical people can manage to be cheerful even while thinking. Meetings seem to have a "first part, a middle part and a last part". There is good opportunity for members to chat together before the meeting and, after a top-notch technical paper, it may happen that the members want to stay and discuss the subject more fully. There is no need to try to compete with social activities in their own coin; we can provide a unique attraction by sticking to our business of aeronautics. We're in favour of the C.A.I. putting up the best in technical meetings. Signs are that our members welcome this method of advancing the art.

R. B. MCINTYRE
*Councillor*

# CHINKS IN OUR FIRST LINE OF DEFENCE†

by S. H. Deeks*

*The Industrial Foundation on Education*

## INTRODUCTION

It was said by Sydney Smith: "The greatest curse that can be entailed on mankind is a state of war. All the atrocious crimes committed in years of peace; all that is spent in peace by the secret corruptions or by the thoughtless extravagance of nations, are mere trifles compared with the gigantic evils which stalk over this world in a state of war. God is forgotten in war; every principle of Christianity is trampled upon."

And yet, notwithstanding such an indictment, the activities of man as recorded upon the pages of our history books are a record of carnage and destruction, of violence and death, of misery and sorrow, all caused by this heartless evil — war.

In the 3,350 years ending in 1860, there were only about 250 years of peace and over 3,000 years in which war in some form or another was being fought. The story of Western civilization is equally striking. From Greece to the League of Nations, there were, on an average, only two years of peace between wars.

Philosophers and sages since the dawn of time have expressed the belief and hope that the day would come when war would no longer curse mankind and violently disrupt his progress towards the goal of the eradication of man's inhumanity to man forever from the face of this old globe of ours with its limitless potential for peace and beauty.

But, notwithstanding these hopes in this modern civilized 20th century, we still have foremost in our thoughts and predominant in our national planning the horrible possibility of war rendered the more hideous by the vast potential of destruction that has been placed into our hands through the prodigious advances in science and technology.

However much we may deplore and deprecate it, we are still faced with the unpalatable fact that war has in the past, still does today, and obviously will in the future, dominate the activities of man. The armaments competition today makes one nation's security another nation's insecurity. Disarmament seems to be impossible and being disarmed today, more so than ever before, is an invitation to disaster and even annihilation, but being disarmed today is a totally different consideration from being disarmed in the past. The transition from the crude club of the cave man to our present chemical, biological, atomic and hydrogen weapons, and the fearful means of delivering them, has been paralleled by a transition from weapons that required little or no modification by man to weapons that require the ultimate in the application of scientific and technological knowledge. This transition has placed an ever-increasing demand upon the adequate development of the intellectual potential of our human resources.

What is more significant is the ever-accelerating pace at which we are travelling. This pace is no better demonstrated than by the statement that there are only two types of combat aircraft today — the experimental and the obsolete.

These conditions make the lack of training in critical areas the equivalent of being disarmed. If aggression occurred today, there would be no time for preparation.

The more study that is devoted to these considerations, the greater the impression becomes that many issues of the future, the outcome of which can be the difference between survival and destruction, are being decided today by the performance of our educational system in our elementary and secondary schools and upon the campuses of our schools of higher learning. In consideration then of the outcome of future struggles for power, whatever form they may take, our educational performance in a sense becomes our first line of defence.

## THE CHINKS IN OUR FIRST LINE OF DEFENCE

In recognition of these changed conditions, we must inevitably raise the question of how our present performance measures up to today's requirements and how our future potential for training may cope with the dynamic conditions we are facing in the future.

This consideration requires a comparison with the performance of other progressive nations of the world but in making these comparisons we have not done so for the purpose of suggesting that because other nations

†Dinner address read at the Mid-season Meeting of the C.A.I. on the 25th February, 1957, in Winnipeg.

*Executive Director.

produce large numbers of certain types of professional people, we should do likewise. It is not quite as simple as that.

It is obvious that the kind of education provided to the people of a nation is one of the principal factors which determines the kind of characteristics the society of that nation is going to possess. It is equally obvious that all nations do not wish to develop the same kind of characteristics and consequently do not require the same performance from their educational system.

Some understanding of the development of these characteristics in other nations and the action that is required of our nation to cope with them in the future is really the essential requirement. The level of education required in a country may be influenced to a very large extent by these considerations. For instance, in such a country as Russia, where the interest has been predominantly in the development of scientific and technological areas of education, their requirements in total on a proportionate basis should be much less than in a country such as ours, where we are interested in remaining competitive in the scientific and technological areas but are predominantly interested in the cultural aspects of education. It would be expected in such cases that, on a proportionate basis, the enrolment in schools of higher learning in Canada would be much greater than it would be in Russia. Notwithstanding this, you are possibly aware of the well-publicized fact that the enrolment in schools of higher learning in Canada is, on a proportionate basis, only 25% of that in Russia and about 35% of that in the United States. These figures, I know, require certain qualifications, but even after making allowances for them the comparison is still a disturbing one.

What may be of more significance to some people is the fact that, notwithstanding the increasing demand for the greater development of the intellectual capacity of our human resources, we are still educating only about 20% of those intellectually capable of absorbing and using higher education.

By whatever standard we may wish to use, it is obvious that we are deficient in providing our people with the level of education that is going to ensure our competitive progress in the complex world of the future.

We have already implied that progress in certain areas of society is dependent upon the level provided in certain specialized areas of education. In view of our dependence for progress and survival on the industrial and economic characteristics of our society, the most critical one with which we can deal today is the area of scientific and technological education. (This does not derogate cultural training. It is really a concern for maintaining an environment in which our culture can freely develop.)

It is paradoxical in the light of this argument to suggest that we are deficient in providing the scientists and engineers we require, on the one hand, and to say, on the other hand, that we have just gone through a period of phenomenal economic growth during the last decade. If there is any substance to this argument, then there must have been a phenomenal growth in the body of scientists and engineers employed in the labour force during this period of economic growth. There was. The number of scientists and engineers increased from about 20,000 in 1945 to about 60,000 in 1955. This, however, was not due to the normal flow of graduates from our universities, but from high immigration and high post-war graduation of veterans. Our present capacity for training engineers and scientists cannot maintain this body and add to it at the rate our growth will require.

So long as we admit the existence of a correlation between economic growth and growth in the body of scientists and engineers, we cannot help but admit that our forward thrust of progress will become blunted against these facts:

(1) The rapid decline in post-war graduations from our universities. For instance, the drop in engineering graduations from the 1950 peak to the number graduated in 1956 was over 50%.

(2) The decline in immigration of professional people. For instance, from 1953 to 1955 immigration of engineers declined over 30%. Recent trends in British emigration to Canada may reverse this trend temporarily, but this is not a long term solution.

(3) The increasing threat of the United States attempting to fill their vacuum from our graduations. For instance, engineers emigrating to the United States increased from a rate of about 200 per year in 1945 to 500 per year in recent years — almost one-third of the number we have graduated. There are many indications that more favourable conditions will lure an ever-increasing number of our hard-won graduates to this apparent land of promise.

And what of the future related to total education? In the light of the avowed intentions of developing the full intellectual potential of their human resources as expressed in words and deeds by other progressive nations of the world, how will we fare? In consideration of the fact that enrolment in the 13 years ending in 1950 in higher education throughout the whole world, with the exception of the U.S.S.R., rose by some 70%, and may be still rising, what possibility is there of us maintaining our present favourable position among the nations of the world? There is no ready-made answer to this but, when we take into consideration the many areas in which we are deficient, it seems obvious that some of the complacency generated by our present prosperity needs to be discarded in favour of bold, vigorous and enterprising actions if we hope to maintain our position. There are obviously many chinks in our first line of defence and it is only by such action that we can hope to provide the material with which to plug them effectively.

**NECESSITY OF A PROGRAMME AIMED AT PROVIDING SOLUTIONS TO OUR EDUCATIONAL PROBLEMS**

The importance of the task that lies before us is so vital that every effort needs to be made to prepare a program that will ensure that the required action is taken and that the sequence of the action taken ensures that first things receive first consideration.

It seems more and more obvious that the performance required of our educational system must be established within the context of existing world-wide developments and an understanding of those underlying factors which

will eventually reflect themselves in the kind of characteristics that both the enemies of our way of life and our competition in the markets of the world may possess in the future.

There seems also to be a need for all of us to develop a greater appreciation of the action necessary to enhance the attributes that characterize us as a democratic and free society.

This is the very broad context within which we must operate. More immediate and practical problems deal with those things mentioned previously. These are: the shortage of secondary school teachers which will inevitably become more critical as the wave of students now going through our schools progresses further into our secondary schools; the shortage of university teaching staff that will worsen with the pending greater enrolment; the shortage of scientific and technological personnel in industry and commerce; the extensive differential between rewards provided for professional people in industry and government compared with education; the need to change the climate of public opinion into adopting a more favourable attitude towards more effort being made to provide greater opportunities for education; and the need to motivate a greater and greater number of our qualified young people to continue with their education.

There are other areas but these are the most urgent. All of us have heard and read much about them from a general point of view and, rather than repeat much of what has already been said, I should like to concentrate more specifically on one particular item which I know is of vital interest to the Canadian Aeronautical Institute. This is the problem of the technician in the area dealing with the shortage of scientific and technological personnel in industry and commerce.

There seems to be little doubt about the fact that the quickest and most feasible way to at least relieve our present shortage of qualified personnel in the scientific and technological areas in industry and commerce is the training of technicians. The area in our educational structure between graduation from secondary school and graduation from university has been a relatively barren one compared with training provided by Western European countries and latterly by U.S.S.R. This applies equally to the United States and it appears most obvious that much of our existing difficulty would have been eliminated on this continent if we had not been negligent in this area.

While some action is possible on an immediate basis, in the long pull, a better definition of the various aspects of technician training needs to be provided and a better understanding of our requirements and objectives developed.

The factor that lies at the very core of this consideration is a definition, generally accepted, of what we mean by a technician. The term, as you know, is badly abused and is associated with all forms of technology, from cooking the family meal to working on a complicated technical problem in aircraft design.

This is not casting any reflection on what has already been done in this area. There have been a great number of people working on this problem who have accomplished much. What they have done can no doubt provide a very effective foundation for future action.

Notwithstanding the progress that has been made, there is a great effort still required. Our experience so far has suggested a number of headings under which a future program might logically be undertaken. These are:

(1) The definition of the technician.

(2) The measurement of the demand for technicians both now and as far as we can logically project it into the future.

(3) The determination of the academic and practical training required for technicians.

(4) The need for professional or sub-professional recognition of technicians.

(5) Consideration of examinations or academic standing which will permit certification of existing technicians.

(6) Consideration of the manner in which training may be provided.

(7) The need for the existence of better communication among all organizations interested in this matter.

(8) The need for accreditation of the various means and courses provided for training technicians within reasonable variations in course content and training methods.

I am not unaware of the fact that action has already been taken in some of these areas in connection with some types of technicians and this is very encouraging. The interest evidenced so far has been phenomenal and I feel sure real progress is a possibility.

I would like to make a few brief general comments on each of these items as suggestions for further consideration.

**The definition of the technician**

In dealing with the definition of the technician, we are confronted with the requirements for technicians in every area of our economy. There is a need for the provision of medical, dental, architectural and many other types. There is no doubt but that these all need consideration, but the one which should be our most vital concern under existing conditions is the technician who possesses the qualifications to assist engineers and scientists either directly, in the drafting office or in the laboratory.

In attempting to define what his qualifications should be, it would appear essential to obtain an understanding of the general conditions he must satisfy. It may be that a more critical examination of the tasks presently being performed by scientists and engineers which could be delegated to a technician should be provided as a guide to the kind and extent of the training they should take.

**The measurement of the demand for technicians**

In dealing with the demand for technicians, it would seem essential to determine the number and kind required both today and in the future as a prerequisite to establishing training programs. In some areas at least, it appears we would have to conduct a survey of the requirements in different types of industry to accomplish this.

**The academic training of technicians**

There seems to be general agreement on the fact that the academic training of technicians is post-secondary school education. While a great variation will no doubt occur in the training required, so far as the application of the fundamentals is concerned, it seems possible from experience that there will be much common ground in the extent of training required in the fundamentals and arts.

**The need for sub-professional recognition of technicians**

The need for professional or sub-professional recognition of technicians seems very essential. Some means of administering the certification of technicians who have become qualified by other than taking a required academic course could be administered in this arrangement. Action has been taken in one area already.

**Examinations or academic standing necessary for certification**

The need for setting examinations for certification arises mainly from the fact that there are many qualified technicians, already employed in our economy, who do not possess the necessary academic training to be entitled to recognition as a particular type or grade of technician. No doubt others will follow in their footsteps in the future.

This would appear to be the most feasible action that could be taken immediately and here again some action has already begun in one area.

Certification of those who have completed an accredited course would present no problem.

**The different manners in which training may be provided**

This is a very extensive subject and for the moment I would like to list these possibilities only:

(1) Existing technical institutes and further expansion of them.

(2) Co-operative schemes, such as the proposed Waterloo scheme.

(3) Existing private schools, both resident and correspondent. Some of these have already been accredited by U.S. accrediting authorities.

(4) In-plant training schemes combined with evening courses in technical institutes or otherwise.

(5) The use of existing technical secondary schools. For instance, in the province of Ontario there are about 60 secondary schools giving technical courses and, in some of these, they provide an additional year's training which is the equivalent or almost so of the first year in a technical institute.

Each of these areas has good possibilities and needs to be explored thoroughly.

**The need for the existence of better communication**

I have been somewhat amazed at the number of different organizations who are interested in the training of technicians and all of them are attempting to do something about such training. In most cases, each seems to be unaware of what the others are doing and no doubt a great amount of good could result from knowing what is being done and proposed in other areas.

A large number of these organizations have approached the I.F.E. requesting us to perform a liaison function among them and we propose to attempt this.

**The need for accreditation**

It appears from the limited investigation that has been carried on so far that there is much to be gained from nationally recognized standards of training. Obviously no one can undertake the task of setting the courses for the different organizations who may be giving this type of training. This is the responsibility and right of each organization.

A satisfactory degree of standardization could be attained, however, by the use of an accrediting procedure for these courses similar to that employed in the U.S.A.

These are preliminary observations which have been suggested to us so far in this area, but a great amount of investigation needs to be carried out before many of them become practical possibilities. As mentioned, a limited amount of work is in progress and I am sure the willingness with which those concerned have co-operated so far provides every indication that these efforts will result in concrete progress in the near future.

**THE NEED FOR A UNIFIED CO-OPERATIVE EFFORT**

I would like, if I may, to return briefly to the broader aspects of our educational problems in Canada. The need for defining our educational problems, of understanding what part each of us should play in finding solutions to them, and of generally promoting a greater appreciation of them on the part of us all has impressed upon us the necessity of better means of communication among those organizations who have an interest in or a responsibility for education in Canada.

Very extensive support has been given to this suggestion and a great many organizations have indicated their willingness to participate in it.

How successful it will be cannot be determined except from experience in attempting to organize such an approach. The degree of its success will only be determined by the co-operation and participation of all these organizations.

If such an effort is organized, the next task that needs to be undertaken is the definition of the part that each of us may play in carrying out the program considered essential. Some exploratory work has been done in this area and it has been suggested that I indicate to you what has developed as the part a professional society, such as your own, might play.

I am doing this on the understanding that this is a preliminary listing only and that it in no sense represents a set goal, but is provided as a basis for further consideration.

The parts that may be played by professional societies that have been suggested so far are:

(a) To assist in the definition of the kind and degree of academic training required in a particular area.

(b) To assist teachers by way of being consultants to them, in developing teaching aids and undertaking part-time teaching programs.

(c) To assist in determining the numbers of the various kinds of professional people that we should train to remain free and progressive.

(d) To provide advice and help to the educational authorities as a guide to them in whatever way this is feasible.

(e) To assist in the task of communicating to their members particularly and to the public generally the nature and magnitude of the problems with which we are dealing and the action that needs to be taken to solve them.

(f) To assist in the accumulation of data, in their particular area, essential to defining our problems in education and forming a program to find solutions to them.

(g) To assist in the task of welding together all the organizations who may wish to associate themselves with a unified approach to solving our educational problems.

Some of these may be of interest to you and others may suggest themselves to you as the picture continues to unfold.

**CONCLUSION**

By correcting the technician deficiency, we will have plugged but one chink in our first line of defence. There are obviously many others that need to be plugged. Even disregarding all these relative considerations, a formidable task lies before us in attempting to provide education for those who will come knocking on the doors of our schools, without any effort to increase the percentage of the age group enrolling in our schools of higher learning. This in itself requires a great additional effort over and above our present performance.

Some of the most fateful history in man's existence is being written today. The action that is taken by you and me, along with every other responsible citizen of this country, may determine whether or not history may say of us as it did of the Babylonian King, "Thou hast been weighed in the balance and found wanting".

A striking parallel may be drawn from our present circumstances and the fateful incident that occasioned the handwriting on the wall. While we enjoy our unprecedented wave of prosperity, an enemy, in terms of today's speed, lies at our gate. Only clear decisive action wisely administered can keep us, joined with our partners in freedom, secure and progressive. It is to be hoped that we possess the moral courage, the understanding, the will and stamina to take such action.

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## F. W. (CASEY) BALDWIN AWARD

A new annual Award, to be known as the "F. W. (Casey) Baldwin Award", has been introduced and will be presented for the first time at the Annual General Meeting in May, 1957.

The Award, consisting of a silver medal, will be presented to the author of the best paper, in terms of originality of material presented and writing skill in presentation, published in the Canadian Aeronautical Journal in the preceding calendar year. The Council will select the winner from three papers recommended by the Publications Committee. (The Turnbull Lecture, though published in the Journal, is not eligible for this Award.)

The Award is named in memory of the late Frederick Walker "Casey" Baldwin who, as a member of the Aerial Experiment Association, flew the Red Wing at Lake Keuka, N.Y., on the 12th March, 1908; and thereby became the first British subject to fly. (J. A. D. McCurdy, the other Canadian member of the Association, was the first British subject to fly in the British Empire, when he flew the Silver Dart at Baddeck, N.S., on the 23rd February, 1909.) Mr. Baldwin was born in Toronto in 1882; he graduated from the University of Toronto in 1907 and his distinguished engineering career was largely associated with speed boats; he died in 1948.

# THE TECHNOLOGY OF GUIDED MISSILES AND ITS EFFECT ON INDUSTRY†

**by R. D. Richmond* and Dr. J. F. Perrier****

***Canadair Limited***

## INTRODUCTION

DURING the past decade considerable interest has been displayed by the armed forces in the application and potentialities of guided missiles. The effort expended in research and development over this period has resulted in the production of several types of missiles.

The objective of this paper is to review some aspects of guided missiles and to communicate the fundamentals that are of particular interest to industry.

The guided missile cannot be considered as a new device since experiments carried out in the United Kingdom during the 1920's produced a type of guided missile in the form of an unmanned airplane. This machine could fly a predetermined course at a predetermined altitude to a preset range and carried a warhead as its payload. The Germans later produced a development of this type known as the V1 which was used during the latter part of World War II. Further experiments were also carried on before 1930 on the remote control of unmanned airplanes based on the transmission of radio signals either from the ground or from a mother aircraft. It is generally accepted however that the German achievement of producing the V1 and V2 in World War II focussed attention on the potentialities of the guided missile. The prospect of combining radar with guided missiles induced further investigation.

## THE GUIDED MISSILE WEAPON SYSTEM CONCEPT

The use of the guided missile as a weapon can only be effective when it is considered as an integral part of the weapon system. The weapon system includes, in part, the varied functions of early warning, target identification, threat evaluation, target acquisition and tracking, and missile operation.

The proper integration of each and every element with one another is of prime importance if the total system is to function satisfactorily. The problems associated with the design of such a system are complex and many, and their solution is limited by practical considerations. An appreciation of these problems can be obtained by considering some of the conditions which must be satisfied for a perfect interception against airborne targets.

(1) The missile must be supplied with errorless course headings calculated from instantaneous and errorless target positions.

(2) The missile must possess a greater speed and manoeuverability than the target, must be equipped with errorless guidance capable of operation at all altitudes, must be capable of control at all altitudes, and must have a one hundred per cent reliable warhead.

(3) The weapon system must be immune to all forms of countermeasures.

(4) The various elements and computers in the weapon system must be programmed correctly.

If all of the above conditions are met, there will be a one hundred per cent probability of completing a successful interception and destroying the target, provided sufficient time is available.

In practice, a weapon system cannot be made to satisfy all of these requirements since, even under the best of conditions, the physical articles are encumbered with tolerances and reliability considerations. It is therefore necessary to express the function of the system in terms of "probabilities" and "degrees of uncertainty".

In recognition of the complexity of the task of designing a weapon system, the term "Systems Engineering" has been added to the engineer's language. Since this term does not appear to possess a concise definition its use is subject to some qualification. Its application to the design of weapon systems usually means that the effect of all elements of the system upon each other and upon the whole must be determined at the beginning and that they be re-evaluated as the system develops.

This approach has been practised to some extent in industry for some time. It is the degree to which this policy must be followed that places a new connotation on its meaning.

In the modern weapon system its importance has been amplified by the need to utilize materials and techniques of design and manufacture, that are lacking in

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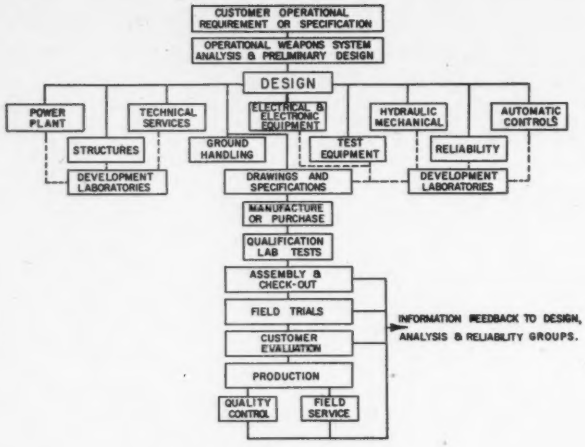


**Figure 1**
**Representative organization work flow chart**

precedent, in a manner that will attain an ultimate result that is nearly perfect. The penalty for ignoring it could be a complete failure of the system which would be incapable of effective repair.

Figure 1 is a simplified weapon system organization chart.

## EVOLUTION OF GUIDED MISSILES

Missiles are classified according to their destination and their point of launch. Thus an air-to-air missile refers to an air-launched missile aimed at an airborne target and a surface-to-air missile refers to a surface-launched missile aimed at an airborne target.

The manner in which the missile is guided to its target will depend, among other factors, upon the nature and range of the target, enemy countermeasures, the desired ability to discriminate between multiple targets, the lethality of the warhead, the time and components available to the designer and, finally, the other elements of the weapon system.

To eliminate any inaccuracies which might result from generalizations, only weapon systems deriving energy either transmitted from or reflected by the target will be considered; inertial and ballistic homing systems are therefore deleted.

Guidance systems can now be placed into two broad classifications: those which do not improve in accuracy as the range from the missile to target decreases and those which do.

The beam rider and command guidance systems fall in the first class. For the former system, the missile is launched and remains within a beam of energy which is directed in such a manner as to track the target. In the latter system, two beams of energy are required — one to track the target and the other to track the missile. A means of transferring commands to the missile must be provided.

In the second class, three divisions are possible: active, semi-active and passive. An active missile carries its own transmitter-illuminator and receiver, generally using the same antenna for both transmission and reception. The semi-active missile does not carry its own transmitter, but relies on illumination of the target from elsewhere. The advantage of semi-active over active is that very high gain illuminators and high illuminating power can be used, whereas the active missile is severely limited in both power and size of antenna due to the small space available. The active missile has the important advantage that, once launched, it proceeds totally independent of the launching installation, while the semi-active missile requires the launching installation to illuminate the target until interception is completed. A passive missile does not require illumination of the target, but uses some characteristic radiation to direct it. A passive infra-red missile which makes use of the heat radiation from the aircraft engines or from skin friction is an example of this type.

All missiles possess power plants and the type of power plant is dependent on the mission and particularly on its range and speed requirements. Short range missiles usually employ one or more solid propellant motors which may be fired simultaneously or in stages. Ramjet or liquid-propelled motors are usually found in medium range missiles and again the liquid fuel motor may be of several stages. Jet engines are usually reserved for longer range missiles; liquid propellant motors may also be used.

As might be expected, there is a marked resemblance between the piloted interceptor and some missiles. In some surface-to-air missiles and some surface-to-surface missiles, the influence of the aeroplane is particularly noticeable. Figure 2 shows a modern piloted interceptor aircraft, the Lockheed F-104. Figure 3 is a sketch of the Boeing Bomarc medium range anti-aircraft missile. Figure 4 is a photograph of the Northrop Snark. These missiles might almost be classed as unmanned aircraft and the techniques used in their design and construction are similar to those used in aircraft. An air-to-air missile, on the other hand, and some short range surface-to-air missiles bear a closer resemblance to a projectile and, in fact, present an entirely new configuration as will be seen in Figure 5, which is a photograph of the Hughes Falcon missile, and Figure 6, which shows a Convair Terrier missile being fired from a ship. The cruciform

**Figure 2**
**Lockheed interceptor F-104**

wing configuration has the attractive characteristic of turning the missile without bank since both wings may be moved simultaneously.

Because of the similarity of purpose and construction of guided missiles and aircraft, it is reasonable that the development of the former should stem from experience gained in the latter. The essential difference is that now the missile must be controlled and guided to its destination by means other than a human crew. To develop the control system of the missile, the various functions performed by the human pilot must be studied in considerable detail and machines must be devised to simulate the necessary functions. These devices, when considered as a system, constitute the analogue computer which replaces the human being. The factors that must be considered when designing this complex analogue will now be discussed.

**Simulation of the human pilot**

The analogue computer cannot incorporate all the combat functions of the human computer, because such matters as judgment in weighing information and ability to handle a change in tactics cannot be built into the computer. The onus is therefore on the designer to plan beforehand the program of the computer for varied enemy capabilities, tactics and countermeasures within a restricted frame of reference. The major weakness of the non-human computer is that it cannot cope with a situation that has not been planned for.

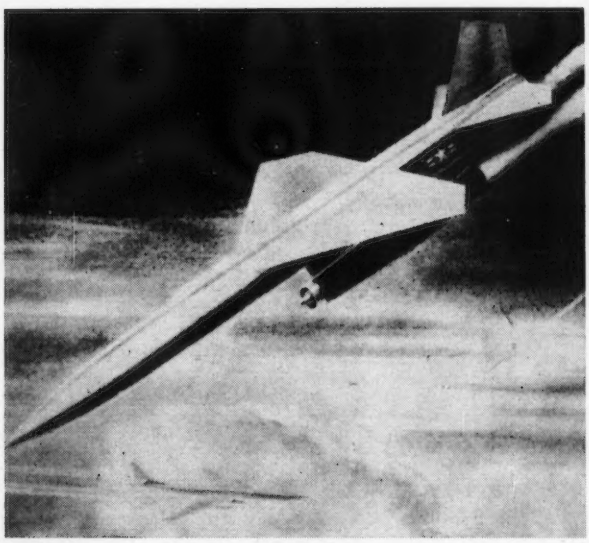

**Figure 3**
**Boeing Bomarc**

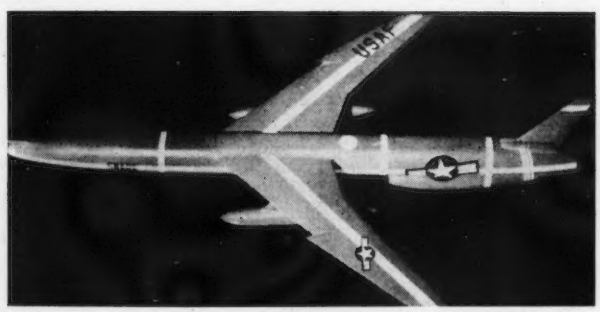

**Figure 4**
**Northrop Snark**

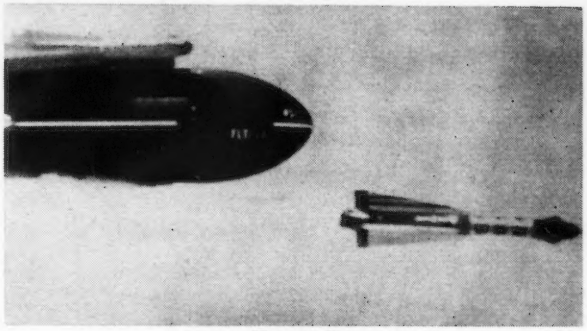

**Figure 5**
**Hughes Falcon**

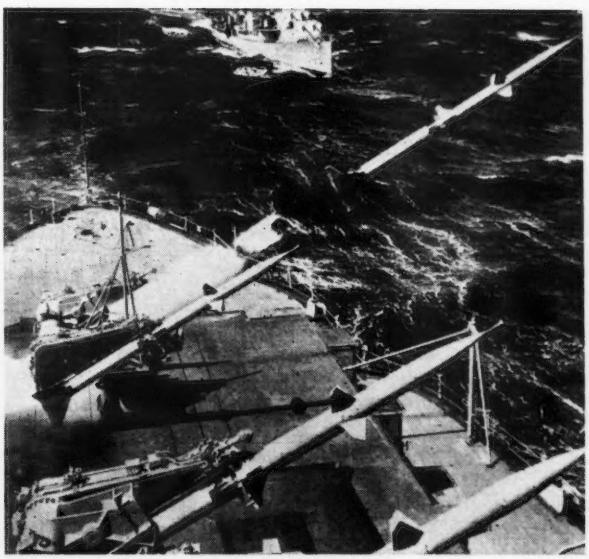

**Figure 6**
**Convair Terrier**

The analogue computer not only has to possess the necessary functions but must also be directed how to use them. In addition it must be reliable and this sets a limitation on the permissible size and scope of the system since reliability and complexity are for the present incompatible.

**Acceleration**

Missile requirements often call for high impulse motors to boost the speed quickly to regions where the control surfaces can perform satisfactorily and the drag is lower. To make efficient interceptions, the missile must be capable also of high lateral and pitch accelerations. The accelerations which the human being can endure are limited and most of the elements used in the aircraft could be readily designed to exceed these limits. Therefore, when the pilot is replaced by an analogue computer, the manoeuverability of the missile can be increased considerably over that of the piloted aircraft. In the present state of the art, this increase may be as much as a factor of five and it must be expected that newer and better devices will extend these limits.

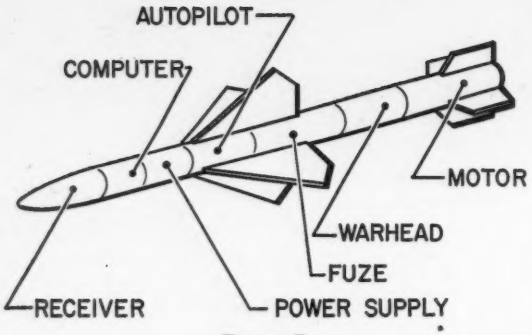


**Figure 7**
**Representative guided missile**

**Environment**

The missile designer no longer needs to plan for an environment suitable to efficient operation of the human computer and, although the tolerances on environment have now been slightly enlarged, a serious problem remains in designing for maintenance of pressure, temperature, humidity and control of vibration within the ranges enforced by the use of present day components. As missiles of higher performance come into use, these problems will become more acute.

**Expendability**

One missile characteristic that challenges ingenuity is its expendability. Expendability and simplicity are usually synonymous. Thus far, missile performance and reliability requirements have been inconsistent with simplicity. The rewards for resolving this incompatibility are obvious.

## DESIGN CONSIDERATIONS

The methods of using a guided missile and the factors influencing the design have been discussed and it is appropriate to consider the design of the missile itself. Figure 7 illustrates a hypothetical guided missile and the units which it contains. The configuration and the disposition of the units have been carefully chosen so as not to represent any particular missile.

Before considering the manner of interconnecting the various units, the term homing system should be defined. The homing system from the standpoint of the missile encompasses the receiver, computer, autopilot and aerodynamics. In addition, the effects of external elements, such as transmission path characteristics and target manoeuvers, must be taken into account. A very simplified block diagram of a missile homing system is given in Figure 8.

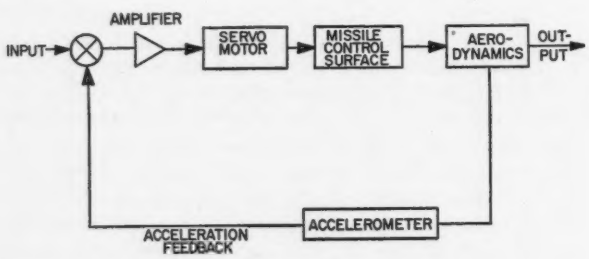


**Figure 8**
**Elementary homing system block diagram**

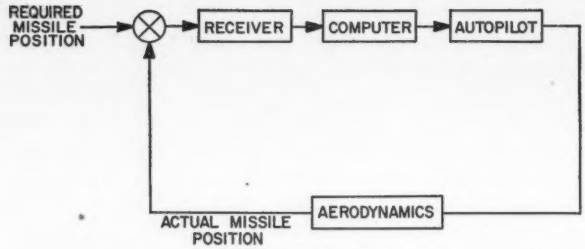


**Figure 9**
**Elementary autopilot block diagram**

The receiver measures the angular position of the target with respect to the missile. Radiation emitted either by the target or reflected from an illuminator located in the missile or at a remote site is processed by the receiver. The radiation may vary in wavelength over the entire electromagnetic spectrum from X-rays through infra-red to long waves. The actual wavelength selected will depend in part upon the attenuation characteristics of the transmission paths and the reflective characteristics of the target. Target angular error information is fed to the computer for transformation into signals corresponding to missile acceleration demands.

The function of the autopilot is to assure that the missile achieves an acceleration equal to the demand by means of aerodynamic controls. The autopilot measures either the airframe attitude or the flight path vector angle and uses this quantity to modify the input to the control surfaces to give the desired relation between the output flight path vector and the input control signal. The airframe in flight is an active element in the missile homing system and is denoted by a single block labelled "missile aerodynamics".

Figure 9 represents a simplified block diagram of an autopilot. Only one loop is shown here, but in practice two or more loops are required for controlled flight. The amplifier delivers an appropriate voltage to drive the servomotors and these in turn actuate the missile control surfaces. The motion of the airframe is measured by a rate gyro or accelerometer which is used as a feedback element to modify the input error signal to the servomotor.

In order to appreciate the physical complexity of these and other assemblies which contribute to the complete missile, it is perhaps of interest to note that one missile having a total volume of 5 cu ft has approximately 5,000 parts down to the electrical and mechanical component level; the majority of these parts are contained in 3 cu ft. A representative set of environmental conditions for this missile is given in Table 1.

TABLE 1
Representative Missile Environmental Conditions

| | |
|---|---|
| Shock | 30 to 70g |
| Vibration | 5 to 10g, zero to 8,000 c/s |
| Lateral accelerations | to 20g |
| Temperature range | −75°F to + 160°F |
| Humidity | to 100% |
| Altitude | Sea level to 80,000′ |

It is therefore apparent that the problem of producing a reliable missile is dependent at least partially on the

number of the components contained in it. To tie these components together, some 4,000 individual connections must be made which quite clearly is another source of unreliability.

The problem of reliability has been and is perhaps one of the most difficult to solve. Although the principles inherent in its solution are simple in theory, they are difficult to implement in practice. To satisfy these principles, firstly, the missile should be designed using reliable and proved components, materials and techniques and, secondly, the manufacturing procedures should be formulated around rigid quality controls. The difficulty in applying these principles is caused primarily by the need to use new techniques and untried components if the missile requirements are to be met. This in turn results in uncovering areas of inexperience in manufacturing and quality control methods.

The use of more intensive testing of components has not of itself improved the reliability of missiles, but has shown that intelligent design and rigid quality control are needed from the outset. It is logical that a judicious combination of the three must be made, for the application of any one by itself will yield diminishing returns. An illustration of the influence of reliability of the individual components on the missile as a whole may be of interest.

A definition of reliability is the probability that a component will operate satisfactorily for a given set of environmental conditions for a given life. To measure the influence of reliability of a given component on the operation of the missile, statistical methods may be used. On this basis, the reliability of any number of components used together is taken as the product of their separate reliabilities. Reliability and kill probability may be related in the weapon system according to the following relation:

$$P_k = P_h \cdot P_r \cdot R_s \cdot R_m,$$

where $P_k$ = kill probability,
$P_h$ = probability of a kill if there is a hit,
$P_r$ = probability of a hit for a reliable missile,
$R_s$ = reliability of launching support system,
$R_m$ = reliability of missile proper.

As an example, if $P_h = 99\%$, $P_r = 90\%$ and $R_s = 90\%$, then for a kill probability of $P_k = 50\%$, a missile reliability $R_m$ of 62% results.

Referring to the missile having 5,000 parts and 4,000 connections or joints, it might be assumed that there are 9,000 possible sources of failure, each of which by itself may be responsible for a complete missile failure. It follows from the definition that, for a missile reliability of 62%, the reliability $R$ for each item is given by

$$(R)^{9000} = 0.62$$

or $R$ is equal to 99.9947%. To show the effect of reducing the number of items, assume that the number of sources of failure can be reduced by a factor of 10. The reliability is now 99.947%. Decreasing the possible sources of failure to 900 has resulted in a relatively small change in item reliability.

The examples just given illustrate the importance of reliable components, but it must be realized that the principle of taking products cannot be applied without reservation and that the assumption of equal reliability must be qualified in practice to reflect factors of experience and the detail design of a particular missile. Reliabilities of the order of magnitude shown may, however, be considered as typical.

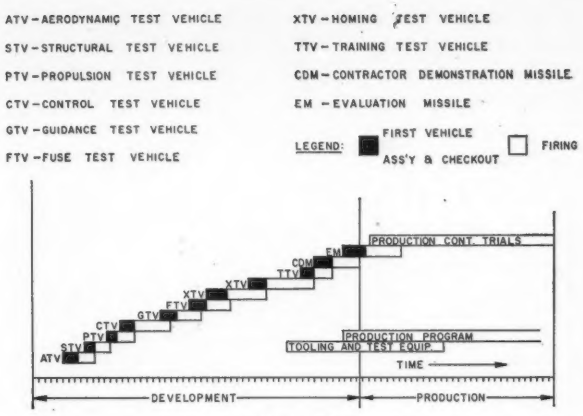


**Figure 10**
**Representative firing schedule ground-to-air missile**

## DEVELOPMENT AND MANUFACTURING

The inherent absence of judgment in a guided missile and the search for reliability have evolved a pattern of laborious investigation in both development and manufacturing organizations.

In both aircraft and missile work, the final proof of acceptance is by flight demonstration.

Since it is usually not possible to carry out more than one flight on any one missile, it is necessary to plan flights utilizing a series of missiles. Due to the influence of one assembly upon another, experience and logic dictate that the performance of each assembly be proved individually. Flight tests are therefore programmed on the premise that each phase is completed satisfactorily prior to the commencement of the next dependent one. In practice, some overlap may result from repeated firings. A typical flight test program is shown in Figure 10 for a surface-to-air missile.

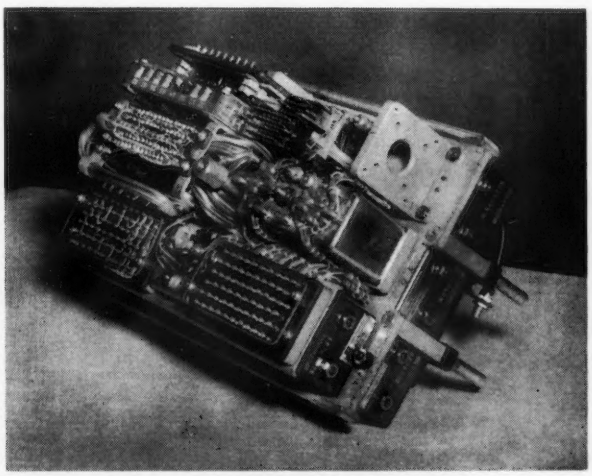

**Figure 11**
**Telemetry package**

**Figure 12**
**Telemetry ground station**

The tests commence with the propulsion and airframe assemblies and the complexity of the test vehicles is increased as the program develops, until the complete missile has been proved. The number used of each type of test vehicle is dependent on obtaining a representative sample of information and on the difficulties that are experienced during the program.

Two or three types of instrumentation are used to acquire quantitative test data. Various optical recording devices are employed to record the behaviour of the test vehicles and, in addition, specific functions within the missile are telemetered to a ground station where they are recorded. Figure 11 is a photograph of a telemetry package which is installed in a missile. Figure 12 is a photograph of the ground station. Airborne miss-distance equipment, installed in either the test vehicle or the target, may be used during the final stages of performance demonstration.

Prior to flight testing an assembly, a considerable amount of laboratory development work is carried out not only with regard to its intended function but to ensure that it will withstand the environment which it will experience in flight. Missile assembly operations are comparable to those used in precision industries and require the application of several skills. Figure 13 is a close-up of the control section of the same missile. Figure 14 is a photograph of a power supply assembly. Each vehicle is meticulously assembled and prepared for flight by subjecting it to an elaborate check-out procedure.

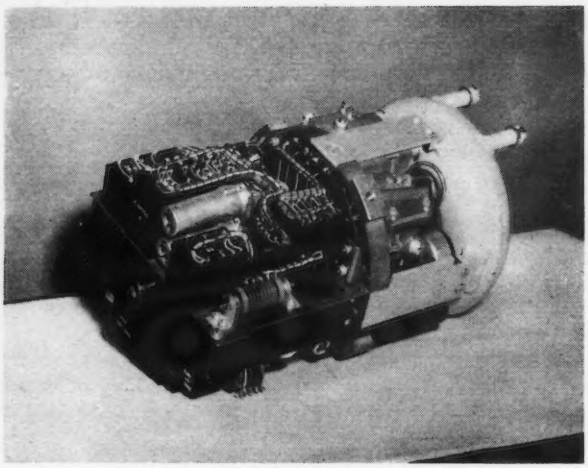

**Figure 14**
**Missile power supply**

Specialized test equipment is used during check-out to simulate the behaviour of the vehicle in flight and to record the attendant functions of both the complete missile and its assemblies. It is not unusual for a vehicle to be processed through check-out several times before it is considered satisfactory. If the flight test is to be carried out at a place removed from the assembly and check-out area, the vehicle is checked out on location prior to flight to ensure satisfactory operation and again it may be taken through several cycles.

Figure 15 is a photograph of one type of test equipment used in the final check-out of a missile. Figure 16 is a photograph of a vehicle mounted in a shock tower. This rig simulates the acceleration that the vehicle will experience during the firing of the motor. Figure 17 is a photograph of a test vehicle mounted in a free-free vibration rig where flight vibrations are simulated. This

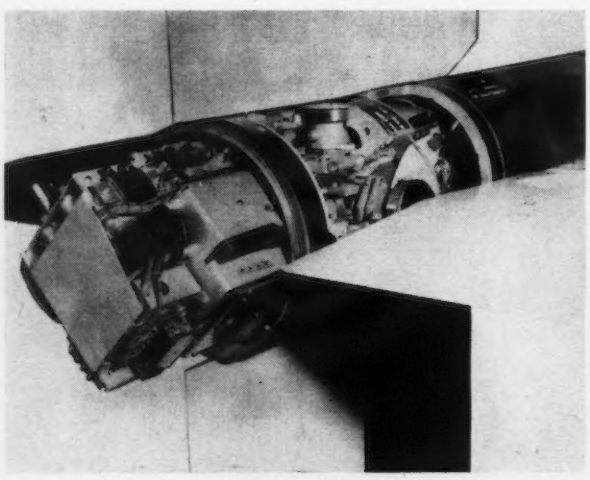

**Figure 13**
**Missile control section**

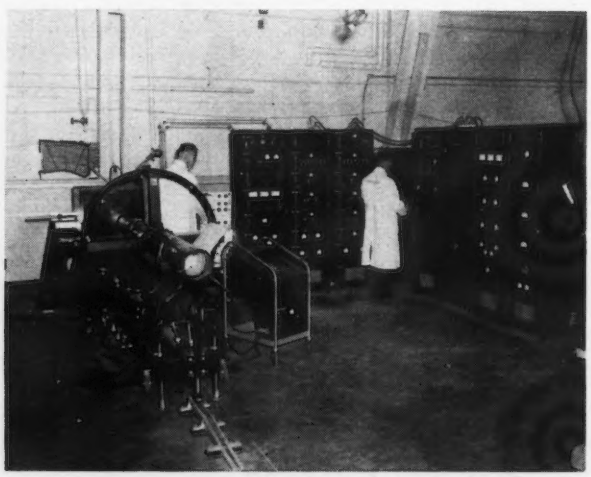

**Figure 15**
**Missile test equipment**

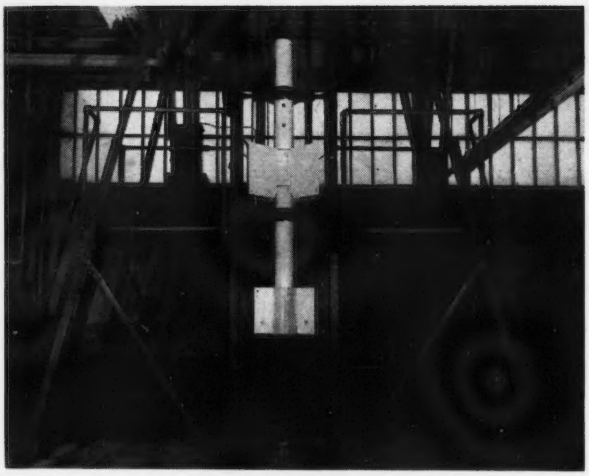

**Figure 16**
**Shock tower**

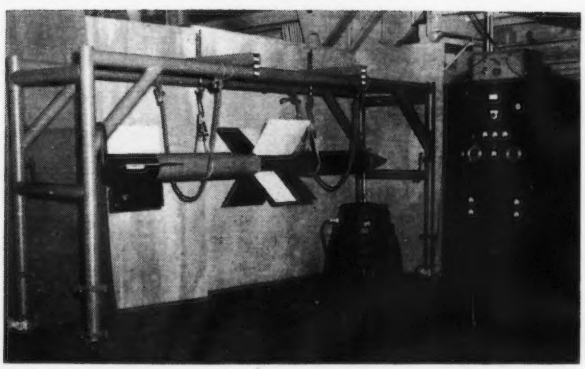

**Figure 17**
**Vibration rig**

test equipment, although tailored for a specific missile, is typical of that used in industry.

The procedures described above have been related to the development of missiles. Their counterparts however are found either in or supplementary to production programs. The need for continual assurance that the product satisfies its design requirements has resulted in a similar meticulous approach to production planning and operations.

Since it is not possible to flight test each missile for acceptance and, further, since a considerable time span may separate factory acceptance and its firing, it is imperative that some verification be obtained as to its reliability and function, prior to its receipt by the customer.

A review of current production programs indicates that two distinctly different philosophies are being practiced in an effort to achieve this goal. One approach utilizes environmental testing, similar to that used during development, as a part of its quality control procedures. At critical stages of sub-assembly and at final assembly, each item is subjected to shock and/or vibration tests. During each test the items are checked for functional defects.

The other approach depends on subjecting components, sub-assemblies, assemblies and the complete missile to type approval tests whose requirements are set beyond the level required by the customer. A limited number of articles are processed through such tests prior to the commencement of volume production, at each significant change point, and on a sampling basis during the production program.

The advocates of the latter philosophy believe that repeated tests tend to shorten the life of individual components which at best may be marginal, with the result that they may pass factory tests but fail in the field. Regardless of which philosophy is adhered to, it is usual to subject 100% of incoming components to functional inspection tests. The success of either approach presumably is dictated by individual circumstances, both with regard to the organization and the particular missile concerned. Figure 18 is a simplified flow chart of a missile manufacturing operation illustrating the application of the first case.

The one factor which is common to either philosophy is the close relationship that must exist between development, quality control, production and its services of procurement and scheduling. During the period of production build-up the absence of precedent and experience necessitates that these groups be organized to reflect the dependence that each has on the other. The "Systems Engineering" concept must continue to prevail past the design phase since it is only through continued re-appraisal of procedures and operations that quantities of missiles have been produced satisfactorily and on schedule.

The introduction of changes into production missiles is one of the regions where this concept is exemplified. In aircraft production, it is possible under conditions of a low calculated risk to release production changes on the basis that they will be flight tested on the first unit. Experience has shown that a missile does not possess as large a capacity to absorb changes on this premise, particularly those of a functional nature. It is considered prudent to introduce a series of test vehicles so as to demonstrate the acceptability of the change prior to production release. The final version of the change may be different from the original and could result in further

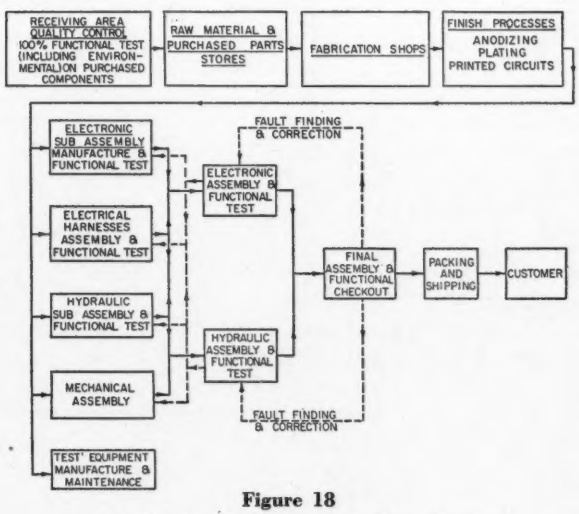
RECEIVING AREA QUALITY CONTROL 100% FUNCTIONAL TEST (INCLUDING ENVIRONMENTAL)ON PURCHASED COMPONENTS
RAW MATERIAL & PURCHASED PARTS STORES
FABRICATION SHOPS
FINISH PROCESSES ANODIZING PLATING PRINTED CIRCUITS
ELECTRONIC SUB ASSEMBLY MANUFACTURE & FUNCTIONAL TEST
ELECTRICAL HARNESSES ASSEMBLY & FUNCTIONAL TEST
HYDRAULIC SUB ASSEMBLY & FUNCTIONAL TEST
MECHANICAL ASSEMBLY
TEST EQUIPMENT MANUFACTURE & MAINTENANCE
FAULT FINDING & CORRECTION
ELECTRONIC ASSEMBLY & FUNCTIONAL TEST
HYDRAULIC ASSEMBLY & FUNCTIONAL TEST
FAULT FINDING & CORRECTION
FINAL ASSEMBLY & FUNCTIONAL CHECKOUT
PACKING AND SHIPPING
CUSTOMER

**Figure 18**
**Production manufacturing flow chart**

**Figure 19**
**Hydraulic assembly and test room**

changes to production operations and the test equipment concerned. The requirement for close co-operation becomes more intensified when mandatory changes arise and the necessity for minimizing the cycle time is of prime importance.

It is a fact that a missile production program must be supported by adequate laboratory and field development facilities staffed with competent personnel who are familiar with the detailed function of all components and assemblies.

The success of any missile program is contingent on the quality of test equipment at its disposal. The provision and maintenance of this equipment can absorb a large number of man-hours, particularly in the early stages of a program. The production of relatively large quantities of missiles has encouraged the development of automatic or semi-automatic testers which can be operated by relatively unskilled labour. Test equipment of this type is referred to as Go-No-Go and, although simple to operate, is complicated in design.

The plant and facilities needed to support a production program are of course dependent on individual requirements of the missile and the production rate. The provision of clean working areas has received general acceptance regardless of the other factors concerned. The assembly of precision parts and some electronic units requires controlled temperature and humidity atmospheres. In some plants all assembly areas are of this type. Figure 19 is a photograph of a hydraulic assembly and test room where filtered air and controlled temperature are provided. If the missile manufacturer is required to handle or store explosives, the accepted provisions must be made for reducing the risk.

## CONCLUSION

The effect that the development and production of guided missiles will have on Canadian industry may be judged from this brief summary of some of their salient features.

During the past few years several companies have been associated with the Canadian Government on the Velvet Glove air-to-air missile program. A basic understanding of missile problems and the approach to their solution has been acquired through the foundation of management and technical groups and supporting facilities. The production or development of missiles can therefore be effectively planned.


# ANNUAL GENERAL MEETING

**CHATEAU LAURIER**

**OTTAWA**

**27th and 28th May 1957**

***Detailed Notices have been distributed to all members***

# ICE PREVENTION IN A CLOUD OF ICE CRYSTALS†

by C. K. Rush*

*National Research Council*

SUMMARY

The formation of ice on aircraft in clouds composed primarily of ice crystals is discussed. Heat requirements for ice prevention are presented for a number of typical meteorological conditions and it is concluded that these may be prohibitive. Some suggestions for avoiding the formation of ice under these conditions are given and it is noted that there is a need for reliable data on the concentrations and characteristics of ice crystals which may be found in clouds.

## INTRODUCTION

Attention has recently been focused on icing problems arising from flight through clouds composed primarily of ice crystals because of the unfortunate experience with the Britannia aircraft[1]. The Proteus engines of this aircraft have been found to be subject to flame-outs when accumulations of slush or ice, resulting from ingestion of ice crystals, shed into the engine compressor. Although ice formation from ice crystals has not received much attention in the past, the problem has been encountered before and studies made of the possible consequences[2, 3]. It is thought that a review of the technical aspects of ice prevention in a cloud of ice crystals would be of interest at this time.

## DISCUSSION OF THE PROBLEM

Normally, aircraft icing is associated with clouds of supercooled droplets and no trouble is experienced in clouds of ice crystals provided that all surfaces which the ice crystals contact are dry and below the freezing point. Under these conditions ice crystals do not adhere to the surface and are carried away in the wind. However, experiments in icing wind tunnels and experience on the North Star icing research aircraft have demonstrated that ice formations will occur on heated surfaces under certain conditions. A necessary condition is that the surface be wet so that impinging ice crystals are caught in the water film instead of bouncing off the surface. Wetting may occur when the surfaces are warmed above the freezing point because some of the ice crystals striking the warm surface are retained long enough for melting to commence. The presence of some supercooled droplets with the ice crystals can also cause a warm surface to be wetted and, if present in sufficient quantity, may cause the surface to be wet whether it is warm or not. Once the surface is wetted, subsequent ice crystals striking the surfaces are readily captured. Now, if the surface is not warm enough to melt each crystal completely before another lands on top of it, a mixture of water and ice occurs on the surface and ice begins to grow in the same manner as ice from supercooled droplets. This ice formation will either slide off in the form of slush or build up into an ice formation the size of which is limited because the surface of the ice as the formation grows becomes colder and eventually goes below the freezing point and no longer traps the impinging ice crystals. Such a formation shields the warmed surface from the wind and more heat is available for ice melting. Thus any adhesion between the ice cap and surface is destroyed and the ice formation may be blown loose with subsequent ill effects depending on the location of the warmed surface.

As mentioned above, the presence of some supercooled water in a mixed cloud may cause an icing surface to be wet. The important parameter here is the freezing fraction which is discussed in References 4 and 5. Briefly, the freezing fraction is the fraction of the supercooled water which freezes where it impinges on the surface in question. If the freezing fraction is 1 then all water is frozen in the impingement area and a dry-ice surface is maintained. The ice so formed is of the rime variety. If the freezing fraction is less than 1 then some water does not freeze in the impingement zone but may run back beyond this zone and freeze. The impingement zone itself is wet and capable of trapping ice crystals.

The freezing fraction is primarily a function of the rate of catch and temperature difference between the surface and the passing air. As the speed of the surface through air increases, both water catch and temperature difference are affected in a way which gives freezing

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fractions less than 1 for smaller and smaller supercooled water contents so that the possibility of wetting in the impingement zones increases as aircraft speed increases. Another factor entering the picture is that of scale for it affects the rate of catch. Thus a surface having a small leading edge radius has a greater specific rate of catch than that of larger radius and as the supercooled water content increases the smaller object is the first to become wet in the impingement zone. This possibility is further enhanced by the supposition that in mixed clouds the supercooled droplets tend to be relatively small compared with those in pure supercooled clouds. It is quite possible that a wing leading edge may ice very little because of its low collection efficiency for small droplets whereas a smaller object, such as a supporting strut in an engine intake, may have a higher collection efficiency with the rate of catch high enough to cause a wet surface. Then the inclusion of ice particles on the icing surface could give a very high rate of ice growth. An examination of some typical cases indicates that this phenomenon of impingement zone wetting in mixed clouds becomes a significant possibility for speeds above 300 mph.

Now, of course, if sufficient heat is supplied to the surface, any ice crystals landing are completely melted and this is no different from the case of supercooled water droplets landing on a thermally anti-iced surface. Unfortunately the heat requirements for ice prevention with ice crystals can be much greater than ice prevention with supercooled water droplets for similar conditions because the latent heat of fusion must be supplied in the case of ice crystals. Thus a heated wing or engine part which is protected sufficiently against icing in supercooled water may not be able to cope with ice crystals.

In order to determine the extent of the increased heat requirements when ice crystal conditions are met, the requirements for a number of typical meteorological conditions were calculated for the two cases of supercooled water droplets and ice crystals.

One of the first requirements in making these calculations is to decide on the rate of catch of the supercooled droplets or ice crystals. There are well established methods for doing this for supercooled droplets and these could be extended to ice crystals if certain information were available. In particular, it is necessary to know the drag characteristics of the ice crystals and also their concentration and range of sizes in the clouds of interest. Such information is not available so that for the purpose of this note equal rates of catch have been assumed for crystals and droplets.

## CALCULATIONS

The calculations are based on methods first proposed by J. K. Hardy and given in Reference 6. For the sake of simplicity, the stagnation point of a 2 in diameter cylinder was selected as the typical case and the total external heat requirements for ice prevention calculated for the following fixed conditions.

droplet diameter, $d$ = 20 microns
surface temperature, $t_s$ = 0°C.
altitude, $H$ = 15,000 ft
cylinder diameter, $D$ = 2 in

The heat to be supplied for anti-icing protection in the case of supercooled water was considered in three parts, viz.

$q_c$ = the heat lost by convection
$q_e$ = the heat lost by evaporation
$q_w$ = the heat required to raise the temperature of the water from the ambient to the temperature of the surface.

For the case of ice crystals $q_w$ was replaced by $q_i$ which is the heat required to raise the ice temperature from the ambient to zero plus the latent heat of fusion required to convert the ice to water.

Four typical combinations of temperature, $T$, and water content, $m$, were selected. The results are presented in Figure 1.

To illustrate the make-up of the total heat requirement, Figure 2 has been prepared and shows the total heat requirements split into the components $q_c$, $q_e$, $q_w$ and $q_i$.

## DISCUSSION OF THE RESULTS

The results show that for the chosen assumptions the heat requirements for ice prevention at the stagnation point on a cylinder are much greater for ice crystals than for supercooled water, as was anticipated. For high water content, the requirements with increasing velocity soon exceed the output of any anti-icing equipment at present envisaged. Even for low water content the requirements are excessive. It will be noted that in the case of supercooled droplets temperature is a more important variable than water content, but that the reverse is the case where ice crystals are concerned.

The effect of speed is interesting. For the supercooled droplets the heat requirement tends to reach a maximum and then drop off as speed increases. This effect is due to the adiabatic heating as speed increases. For the ice crystals this influence is also evident but is completely outweighed by the heat requirement to overcome the latent heat of fusion so that the total heat requirement continuously increases with increasing speed. This rapid increase in heat requirement with increasing speed is very striking. It stems primarily from the increasing rate of catch which approximately doubles when speed doubles. With supercooled droplets the same increase occurs but the heat required to bring the supercooled water caught on the surface to a temperature above freezing is small compared with that required to melt the ice crystals.

Now it must be admitted that the assumption that the rate of catch of ice crystals is equivalent to that of supercooled water droplets is open to question. It is thus difficult to specify the magnitude of the problem on the basis of available information but experience in icing tunnels and in flight, particularly the recent Britannia difficulties, demonstrates a serious problem which must be faced.

Fortunately a simple cure is available for many cases for it is only necessary to keep the surfaces on which ice crystals will impinge below the freezing point. Thus the thermal anti-icing and de-icing systems should not be used in ice crystal clouds. Since it is sometimes difficult to tell which kind of cloud exists from visible observations it is important to develop a means of controlling the thermal anti-icing and de-icing systems which is actuated solely by the presence of ice-forming conditions

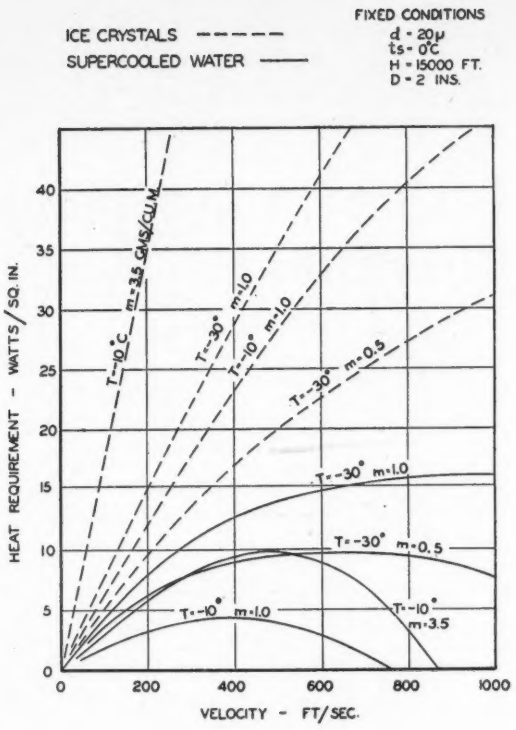


**Figure 1**

**Total external heat requirement for ice prevention at the stagnation point on a cylinder**

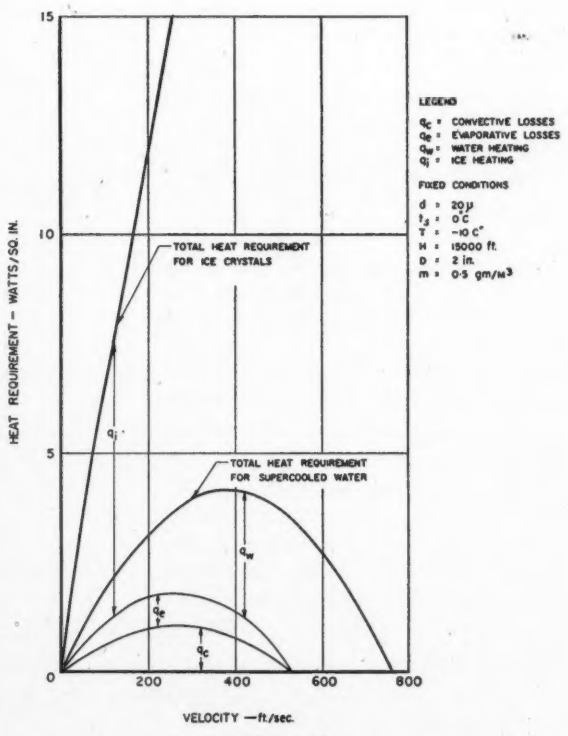


**Figure 2**

**Make-up of total external heat requirement for ice prevention at the stagnation point on a cylinder**

and which clearly distinguishes between supercooled water droplets and ice crystals or snowflakes. The orifice type of ice detector appears to offer the best approach for this kind of system.

As previously mentioned, supercooled droplets may be present with the ice crystals. If they represent a small percentage of the total water content then the ice formed on cold surfaces will be a rime type which has a dry surface and therefore will not trap impinging ice crystals. The rate of icing will be very low and, unless very prolonged flight in this mixed condition is undertaken, should not give rise to trouble. If the supercooled droplets represent a large percentage of the total water content then the surface may be wet and collect the ice crystals. However since the percentage of ice crystals is low the heat requirement to keep the surface ice free will be only moderately greater than for the same water content of supercooled droplets only.

In dealing with specific problems where surfaces are unavoidably heated due to some function other than anti-icing or de-icing, it would seem best to examine the possibility of shielding the surface so as to present a cold shield to the ice crystals. If it is decided to heat the surface sufficiently to take care of the ice crystals then it must be realized that the heat requirements are likely to be severe as demonstrated by the previous calculations.

## CONCLUSIONS

(1) Experience in flight and in icing wind tunnels demonstrates an icing problem when wetted surfaces are exposed to clouds of ice crystals.

(2) Theoretical calculations show that the heat requirements for ice prevention are greater for ice crystal conditions than for equivalent supercooled droplets.

(3) The operation of thermal ice prevention equipment should be avoided in ice crystal clouds.

(4) Where trouble is encountered because surfaces are inadvertently warmed during passage through ice crystal clouds, it seems best to first seek a solution through cooling the surface to below freezing or shielding it with a cold surface. If this is not possible, the system must be designed to take care of ice crystals.

(5) There is a need for reliable data on the concentrations of ice crystals which may be found in clouds and also their collection efficiency.

## REFERENCES

(1) *Editorial,* FLIGHT, SEPTEMBER 28, 1956.

(2) Rush, C. K. and Wardlaw, R. L. – *Wind Tunnel Simulation of Atmospheric Icing Conditions,* PAPER PRESENTED TO FIFTH GENERAL ASSEMBLY OF AGARD, OTTAWA, 1955.

(3) Orr, J. L., Milsum, J. H. and Rush, C. K. – *Electro-Thermal De-Icing Systems: Their Design and Control,* NAE REPORT LR 70, 1953.

(4) Dickey, T. A. – *An Analysis of the Effects of Certain Variables in Determining the Form of an Ice Accretion,* U.S. NAVY AEL REPORT 1206, MAY, 1952.

(5) Messinger, B. L. – *Equilibrium Temperature of an Unheated Icing Surface as a Function of Airspeed,* JOURNAL OF THE AERONAUTICAL SCIENCES, VOL. 20, P 29, JANUARY, 1953.

(6) Tribus, Myron – *Modern Icing Technology,* PROJECT M 992-E, AIR RESEARCH AND DEVELOPMENT COMMAND, USAF, 1952, ENGINEERING RESEARCH INSTITUTE, UNIVERSITY OF MICHIGAN.

# A SURVEY OF THE ADVANTAGES OF TRANSISTORS IN AIRBORNE ELECTRONIC EQUIPMENT†

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## SUMMARY

An examination of the electronics equipment carried by a typical airliner indicates that effective use of transistors will be possible in such aircraft. The examination consists of evaluating each separate vacuum tube application, then applying savings factors for space, weight and power. The result indicates significant increases in economy, either through lower costs or aircraft construction or increased revenue earning capacity.

## INTRODUCTION

It is difficult to make accurate generalizations in a science so new and so fluid as semiconductor electronics. However, most observers agree that transistors have certain distinct advantages over vacuum tubes in electronic circuits on the one hand and suffer from certain disadvantages on the other. Undoubtedly many of these disadvantages will eventually be removed or alleviated by progress in the technical sciences associated with semiconductor production. Considering this as well as their present recognized advantages, it is certain that transistors will continue to appear in greater numbers in all classes of electronic equipment[1]. This paper was undertaken in anticipation of this trend, since it seemed worthwhile to examine in advance, so far as it may be possible, some of the benefits to be expected by using transistors. It was decided to concentrate on the aircraft industry, for which purpose a Super Constellation airliner was selected as an example, although other fitting examples abound in aviation and other industries.

## COMPARISON OF TUBE AND TRANSISTOR EFFICIENCIES

It is well known that transistors require no filament current, but it is not so well known that they require significantly lower electrode power inputs than vacuum tubes of comparable circuit performance. This can be illustrated by choosing a 6J5 triode and supposing it to be operated in Class A configuration into a load resistance of 100,000 ohms at, say, a plate voltage of 300 volts as in Figure 1. When fully driven its power output is equivalent to the area shown shaded in Figure 1, i.e.,

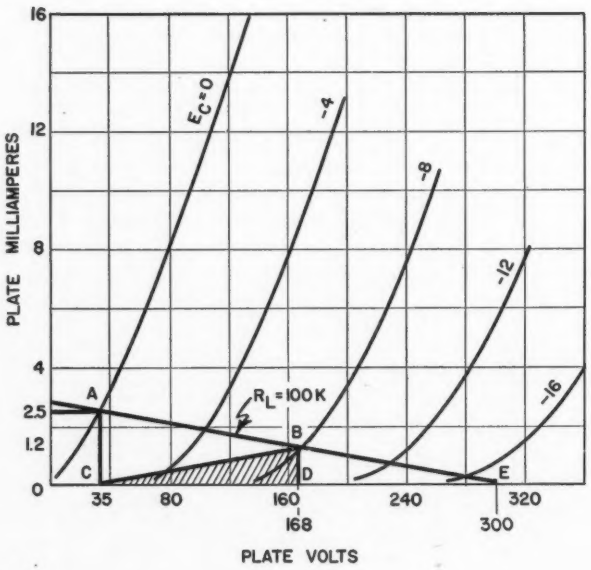


**Figure 1**

**Type 6J5—Average plate characteristics**

$$P_{o(p)} = (300 - 35)(2.5 - 0)/8 = 82.7 \text{ mw} \quad (1)$$

The power input to the plate is the product of plate voltage and plate current computed at the operating point *B*;

$$P_{i(p)} = (167.5)(1.25) = 210 \text{ mw} \quad (2)$$

The total power input to the tube should include also the power supplied to the filament, which is

$$P_{i(f)} = (6.3)(.3) = 1.89 \text{ W, or } 1890 \text{ mw} \quad (3)$$

Thus the total power supplied to the tube is

$$P_{i(t)} = P_{i(f)} + P_{i(p)} = 2100 \text{ mw} \quad (4)$$

and the efficiency is

$$E_{(\text{tube})} = P_{o(p)}/P_{i(t)} = 82.7_{(100)}/2100 = 3.94 \text{ percent} \quad (5)$$

But is should be noticed that the plate efficiency, ex-

†Paper read at the I.A.S./C.A.I. International Meeting in Toronto on the 27th November, 1956.

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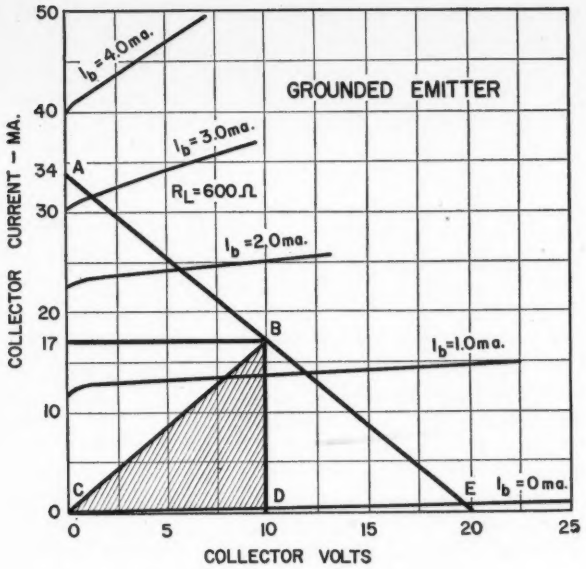



**Figure 2**

**T.1 Type 2N185—Average collector characteristics**

clusive of the wastage of filament power (which contributes nothing to the tube's role as an amplifier, apart from providing a source of electrons), is only

$$E_p = 82.7_{(100)}/210 = 39.4 \text{ percent} \quad (6)$$

This low plate efficiency arises from the inability of the input signal voltage to drive the grid positive, with the result that its operating regime is severely restricted, as seen in Figure 1, being limited to the region between *A* and *E* on the loadline.

Consider, however, the performance of a transistor like the Texas Instruments type 2N185 operated at a collector voltage of 20 volts into a load of about 600 ohms. Its lower output, which is the shaded area of Figure 2, is

$$P_{o(c)} = (20.0 - .5)(34 - 1)/8 = 82.8 \text{ mw} \quad (7)$$

which is equivalent to that of the 6J5 triode. But the power input to the collector is only

$$P_{i(c)} = (10)(17) = 170 \text{ mw} \quad (8)$$

so that the collector efficiency is seen to be

$$E_c = E_{(\text{transistor})} = 82.8/170 = 48.6 \text{ percent} \quad (9)$$

Thus the electrode efficiency of the transistor is about 9.2 per cent higher than that of the tube. This greater efficiency is possible with the transistor because the signal excursion is limited only by the extremes of the load line, points *A* and *E*, Figure 2, and not only by a portion of it as in the vacuum tube. But the filament power of the tube must also be taken into account when reckoning overall efficiency, considering that the wasted power of the 6J5 is as much as 96.1 per cent of its input power, while that of the transistor is only 53 per cent of its input power.

To compare the actual amounts of wasted power in the above example, form the ratio

$$(170 - 82.8)/(2100 - 80.0) = .043 \quad (10)$$

which is the ratio of wasted power in the transistor to that in the tube. The transistor wastes only 4.3 per cent of the amount wasted by the tube, which is equivalent to saying that, if the transistor were substituted for the tube, the waste power would be cut by 95.7 per cent while obtaining the same circuit performance. Although this is a comparison taken at random, variations in circuit applications and differences between the many kinds of transistors and tubes in use would be such that the average expected power saving would be about 95 per cent instead of the higher figure shown.

### RELATIVE SIZES OF TRANSISTOR AND TUBE CIRCUITS

Turning now to the comparison of size between the tube and the transistor, it is seen that the tube volume is 9.2 cubic inches while the transistor's is only .06 cubic inches. But the differences in their sizes alone is not the only factor, since the transistor will also permit less power consumption to occur in its associated circuits than will the vacuum tube, and this will mean that smaller circuit elements can be used. The result is that much circuit space also can be conserved with transistors. Now the average computed power density for fourteen airborne equipments is about .09 watts per cubic inch. It seems unlikely that germanium transistors could operate effectively in such a high power density since associated ambient temperatures are often greater than 150°C, which is fatal to germanium transistor operation. Silicon transistors, however, operate satisfactorily at these temperatures, for which reason they alone should normally be considered for hybrid equipments, i.e., equipments that use both transistors and vacuum tubes. A much more appropriate power density for germanium transistors would be about 10 per cent of that for tubes, or about .01 watts per cubic inch. The transistor in the above example dissipates about .17 watts, while its external circuit would dissipate another .10 watts, making a total of .27 watts. Using the estimated maximum power density of .01 watts per cubic inch, it is evident that the average volume needed per transistor stage will not exceed about 27 cubic inches.

The average volume per vacuum tube stage taken over nine randomly selected equipments was 132.5 cubic inches. By using a transistor instead of a tube the difference represents a saving in space of about 105 cubic inches per stage, which is appropriate to a saving of about 80 per cent. Many practical experiences in actual conversion, some of which have been reported[2], lend weight to the reasonableness of this figure for estimating purposes and the subsequent analysis is based on this space reduction factor.

### RELATIVE WEIGHTS OF TRANSISTOR AND TUBE CIRCUITS

It is more difficult to estimate the amount of weight saved by using transistors. Where complete transistorization is possible, the total elimination of dynamotors and power transformers, the reduction in size and weight of other components resulting from lower insulation and power dissipation requirements and the much lighter weight of the transistors themselves and their sockets may lead to weight savings up to 95 per cent. On the other hand, the presence in many equipments of weighty

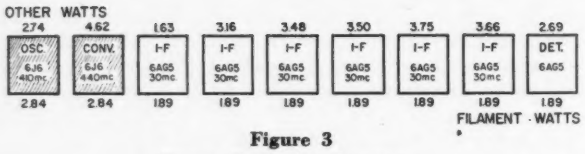



**Figure 3**
**Power dissipation by stages**

**Figure 4**
**Power dissipation by stages**

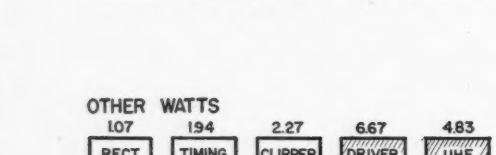



**Figure 5**
**Power dissipation by stages**

mechanical components like servo drives, tuning mechanisms, electrically actuated switches and indicators that cannot be eliminated may reduce the actual weight saving to only a few per cent, especially in equipments that contain relatively few vacuum tubes like the 18OL-3 antenna tuner carried in many aircraft. Accordingly, it was decided to use the weight savings factor of 90 per cent advocated by Texas Instruments[2] and treat equipments with complications in a more direct way.

**METHOD OF ESTIMATING BULK AND POWER SAVINGS**

With these estimated savings factors of 95 per cent on power, 80 per cent on space and 90 per cent on weight, it is possible to evaluate some of the advantages of conversion. The AVQ-9 Radar Altimeter is selected for three reasons: (a) it contains receiver, indicator and transmitter components, enabling a comparison of results to be made; (b) none of the components can be fully transistorized, so that the method adopted for dealing with hybrids can be presented; (c) it is a common and important piece of airline navigational equipment.

The first step is to divide the altimeter into its three components: receiver, transmitter and indicator. Next, each of these components is broken down into stages as in Figures 3, 4 and 5. The total power consumed by the equipment is then apportioned out to the various stages as shown. In each case the filament power is distinguished from all other powers consumed per stage. Then a decision is made respecting each stage whether or not its function could be served with transistors, the basis for decision being the operating frequency of the stage, its sensitivity and its power level. With transistors currently available, it would be possible to transistorize any stage whose plot falls within the shaded area of Figure 6, but no stage outside it. To each stage is then applied the savings factors mentioned above, if it is transistorizable.

The estimated power required for a transistorized stage is arrived at quickly by computing five per cent of the total power taken by the original vacuum tube stage. Original power consumed by non-transistorized stages is assumed to remain unchanged for those stages in the transistorized hybrid. Table 1 (A) shows a power budget for the AVQ-9 before and after conversion. Consider the receiver portion, which consumes a total of 48.1 watts before transistorization. The R-F amplifier and mixer stages operate in the UHF spectrum and could not therefore be transistorized at this time. The remaining seven stages operate at power, frequency and noise levels that permit transistorization with various degrees of difficulty. Accordingly it is assumed that the

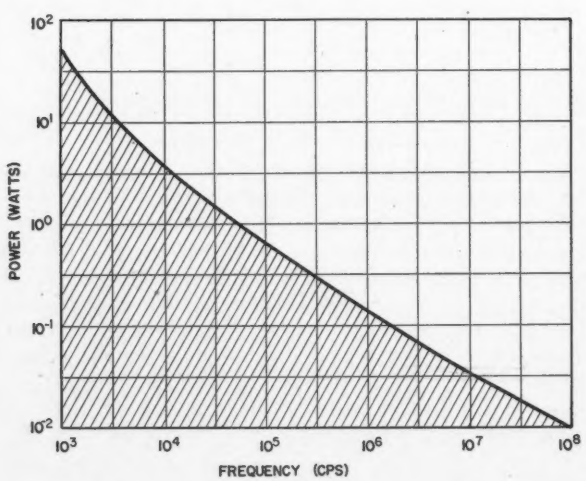



**Figure 6**
**Range of circuit applications open to present transistors**

power requirement for the first two stages will remain at 13 watts after transistorization. The other stages will require, after transistorization, only 5 per cent of the power needed before transistorization, or about 1.8 watts. Thus the total required power for a transistorized AVQ-9 receiver is 14.8 watts, representing a saving of 33.33 watts or 69.3 per cent.

The method adopted for estimating the weight and volume of the transistorized equipment is indirect and is reached in the following way. The volume of equipment per unit of consumed power is computed for the entire receiver. It is then assumed that the volume/power ratio applies uniformly throughout, i.e., if there are two stages present where one dissipates twice the power of the other, its tube and associated circuit components will occupy twice the volume of the other. This assumption may be only approximately valid; nevertheless, it permits an estimate to be made of the volume savings to be expected when one or more vacuum tubes are replaced, providing the power dissipated in the tube and its associated circuits is known. For example, the original receiver occupies 390 cubic inches and its overall power consumption is 48.1 watts, yielding a power density of .12 watt/cubic inch. Now, from Figure 3, the two stages that cannot be transistorized, shown shaded, consume a total of 13.0 watts. There is no reason to suppose that these stages will consume either more or less power than before and it is assumed that the power density associated with this non-transistorized portion of the receiver will remain unchanged. Consequently, it is estimated that the two non-transistorized stages will require a volume equal to

$$V = \frac{\text{Pwr diss. of non-trans. stages}}{\text{Orig. pwr/vol ratio}} = 12.0/.122 = 106.7 \text{ cu in} \quad (11)$$

Now the difference between this 106.7 cubic inches and the original volume represents the volume of the transistorized portion of the receiver, i.e., 283.3 cubic inches. The estimate of 80 per cent volume savings is now applied to the 283.3 cubic inches of transistorized stages, and an estimated volume of 56.6 cubic inches is obtained for the transistorized portion. Now here an apparent anomaly appears between this result, where seven transistors are assigned a volume of 56.6 cubic inches, and the preceding discussion, where only one transistor needed 27 cubic inches. It was noted that the power density of the 2N185 should not exceed .01 watt/cubic inch. The seven transistors in the AVQ-9 would operate at much lower power levels, their total consumption being only 1.8 watts. Thus the power density is only .005 watt/cubic inch for the transistorized portion if it were isolated from the vacuum tube portion. If not isolated, these transistors would of course be immersed in an ambient power density of .06 watt/cubic inch and the necessity for using silicon transistors could probably not be avoided.

The method used for computing weight savings was similar to that used above for computing volume savings. Here it was assumed that the weight/watt consumed in each non-transistorized stage would remain the same after all transistorizable stages were converted. In the AVQ-9 receiver, the original weight allotment was .14 pounds/watt. It is assumed that the two non-transistorized stages will have a weight equal to

$$W = \frac{\text{Pwr diss. of non-trans. stages}}{\text{Orig. pwr/wright ratio.}} = 13.0/7.2 = 1.8 \text{ lb} \quad (12)$$

The difference represents 4.7 lb of equipment that is fully transistorized and which, according to the reduction factor introduced above, can be reduced in weight by about 90 per cent. It should be noted that there are no weighty dissipation-less elements present to conflict with the hypothesis that weight and liberated heat are uniformly distributed throughout the equipment. This leads to an estimated final weight for the transistorized portion of .5 lb. The total new weight is 2.3 lb and the weight efficiency of conversion is 64.6 per cent, appropriate to an actual saving of 4.2 lb.

The transmitter and indicator were treated in the manner described above and their power, volume and weight budgets are shown in Tables 1(A), 1(B), and 1(C) respectively together with the combined figures for the entire altimeter. From these it can be seen that

TABLE 1
POWER, VOLUME AND WEIGHT BUDGETS FOR AVQ-9 RADAR ALTIMETER BEFORE AND AFTER TRANSISTORIZATION

(A) Power Budget

| Component | Before | After | | Savings | |
|---|---|---|---|---|---|
| | Tube Watts | Tube Watts | Transistor Watts | Watts | % |
| Receiver | 48.1 | 13.0 | 1.8 | 33.3 | 48.3 |
| Transmitter | 48.4 | 29.2 | 1.0 | 18.2 | 37.6 |
| Indicator | 25.5 | 4.9 | 1.0 | 19.6 | 76.9 |
| Combined | 122.0 | 47.1 | 3.8 | 71.1 | 51.0 |

(B) Volume Budget

| Component | Before | After | | Savings | |
|---|---|---|---|---|---|
| | Tube cu in | Tube cu in | Transistor cu in | cu in | % |
| Receiver | 390.0 | 106.7 | 56.6 | 226.7 | 58.1 |
| Transmitter | 646.0 | 390.0 | 49.2 | 206.8 | 32.0 |
| Indicator | 494.7 | 93.5 | 80.2 | 321.0 | 65.0 |
| Combined | 1530.7 | 590.2 | 186.0 | 754.5 | 49.0 |

(C) Weight Budget

| Component | Before | After | | Savings | |
|---|---|---|---|---|---|
| | Tube lb | Tube lb | Transistor lb | lb | % |
| Receiver | 6.5 | 1.8 | 0.5 | 4.2 | 64.3 |
| Transmitter | 6.6 | 4.1 | 0.2 | 2.3 | 34.8 |
| Indicator | 10.0 | 1.9 | 0.8 | 7.3 | 73.0 |
| Combined | 23.1 | 7.8 | 1.5 | 13.8 | 59.7 |

the transmitter portion offers the least advantages with transistors, though power, volume and weight savings of 37.6, 32.0 and 34.8 per cent respectively can be achieved. The chief reason for the low conversion efficiency with the transmitter is that the non-transistorized stages consume more than half of the total power, volume and weight and the savings factors can be applied only to the remainder. It is not so with the receiver, since these quantities are more uniformly distributed throughout the equipment. The indicator is a special problem because the only non-transistorized stage, the indicator tube, occupies about one-fifth of the total space available. Consequently, the volume savings for the indicator are lower than the power and weight savings. The overall equipment budgets are also shown in Tables 1(A), 1(B) and 1(C), from which it is apparent that power, volume and weight savings of 51.0, 49.0 and 59.7 per cent respectively can be achieved.

### ANALYSIS OF SUPER CONSTELLATION ELECTRONIC EQUIPMENT

The method of analysis was extended to eleven other equipments fitted in one Super Constellation as shown in Table 2, which also shows the total number of tubes that can be eliminated and the total number of transistors required in doing so. The power, volume and weight budgets for the eleven equipments are shown in Tables 3, 4, and 5 with the indicated totals. From the result, it appears that a total power saving of 1,866.5 watts, volume savings of 16,000.5 cubic inches and weight savings of 470.3 lb should be possible in the aggregate.

TABLE 2

TRANSISTORIZABLE EQUIPMENT FITTED IN A TYPICAL SUPER CONSTELLATION, WITH APPROXIMATE NUMBER OF TUBES ELIMINATED IN CONVERSION

| Model No. | Description | Complement | | |
|---|---|---|---|---|
| | | Before | After | |
| | | Tubes | Tubes | Transistors |
| 51X–1 | VHF Receiver | 19 | 0 | 23 |
| TA–18B | VHF Transmitter | 11 | 3 | 10 |
| 51R–3 | VOR Receiver | 26 | 0 | 33 |
| 51R–3 | VOR Receiver | 26 | 0 | 33 |
| 51V | Glide Slope Receiver | 12 | 9 | 12 |
| G 269 | Public Address Amp. | 4 | 0 | 5 |
| AR 144 | HF Receiver | 7 | 0 | 9 |
| AR 144 | HF Receiver | 7 | 0 | 9 |
| AT 144 | HF Transmitter | 10 | 5 | 6 |
| AT 144 | HF Transmitter | 10 | 5 | 6 |
| MN 53B | Marker Receiver | 7 | 0 | 9 |
| MN 32A | Multichannel Amp. | 6 | 0 | 8 |
| 180 L–3 | Antenna Tuner | 3 | 0 | 6 |
| MN 62 A | Compass Receiver | 15 | 0 | 19 |
| MN 62A | Compass Receiver | 15 | 0 | 19 |
| AVQ–9 | Radio Altimeter | 19 | 5 | 18 |
| R–9/APN4 | Loran Receiver | 13 | 0 | 17 |
| 1D-6/APN4 | Loran Indicator | 28 | 1 | 46 |
| | Total | 238 | 28 | 288 |

TABLE 3

POWER BUDGET FOR 18 ELECTRONIC EQUIPMENTS FITTED IN A SUPER CONSTELLATION AIRCRAFT BEFORE AND AFTER TRANSISTORIZATION

| Model No. | Description | Before | After | | Savings | |
|---|---|---|---|---|---|---|
| | | Tube Watts | Tube Watts | Transistor Watts | Watts | % |
| 51X–1 | VHF Receiver | 303.0 | 130.0 | 8.6 | 164.4 | 54.2 |
| TA–18B | VHF Transmitter | 385.0 | 300.0 | 4.3 | 80.7 | 21.0 |
| 51R–3 | VOR Receiver | 180.0 | 55.7 | 6.2 | 118.1 | 65.6 |
| 51R–3 | VOR Receiver | 180.0 | 55.7 | 6.2 | 118.1 | 65.6 |
| 51V | Glide Slope Rec. | 63.0 | 15.0 | 2.4 | 45.6 | 72.3 |
| G 269 | Public Address Amp. | 123.0 | 0.0 | 26.4 | 96.6 | 78.5 |
| AR 144 | HF Receiver | 58.0 | 0.0 | 3.0 | 55.0 | 95.0 |
| AR 144 | HF Receiver | 58.0 | 0.0 | 3.0 | 55.0 | 95.0 |
| AT 144 | HF Transmitter | 1340.0 | 1070.0 | 5.0 | 265.0 | 19.8 |
| AT 144 | HF Transmitter | 1340.0 | 1070.0 | 5.0 | 265.0 | 19.8 |
| MN 53B | Marker Receiver | 43.3 | 0.0 | 2.2 | 41.1 | 95.0 |
| MN 32A | Multichannel Amp. | 26.6 | 0.0 | 1.4 | 25.2 | 95.0 |
| 180L–3 | Antenna Tuner | 71.0 | 56.0 | 0.8 | 14.2 | 20.0 |
| MN62A | Compass Receiver | 152.0 | 54.5 | 4.8 | 92.7 | 61.0 |
| MN62A | Compass Receiver | 152.0 | 54.5 | 4.8 | 92.7 | 61.0 |
| AVQ–9 | Radio Altimeter | 122.0 | 47.1 | 3.8 | 71.1 | 58.3 |
| R–9/APN4 | Loran Receiver | 125.0 | 0.0 | 6.0 | 119.0 | 95.0 |
| 1D–6/APN4 | Loran Indicator | 163.0 | 8.0 | 8.0 | 147.0 | 90.0 |
| | Total | 4884.9 | 2916.5 | 101.9 | 1866.5 | 38.2 |

TABLE 4

VOLUME BUDGET FOR 18 ELECTRONIC EQUIPMENTS FITTED IN A SUPER CONSTELLATION AIRCRAFT BEFORE AND AFTER TRANSISTORIZATION

| Model No. | Description | Before | After | | Savings | |
|---|---|---|---|---|---|---|
| | | Tube cu in | Tube cu in | Transistor cu in | cu in | % |
| 51X–1 | VHF Receiver | 828.0 | 414.0 | 83.0 | 331.0 | 40.0 |
| TA–18B | VHF Transmitter | 1945.0 | 1510.0 | 88.0 | 347.0 | 17.9 |
| 51R–3 | VOR Receiver | 1607.0 | 188.0 | 284.0 | 1135.0 | 70.9 |
| 51R–3 | VOR Receiver | 1607.0 | 188.0 | 284.0 | 1135.0 | 70.9 |
| 51V | Glide Slope Rec. | 770.0 | 186.0 | 116.8 | 467.2 | 60.6 |
| G269 | Public Address Amp. | 730.0 | 0.0 | 146.0 | 584.0 | 80.0 |
| AR144 | HF Receiver | 2325.0 | 0.0 | 465.0 | 1860.0 | 80.0 |
| AR144 | HF Receiver | 2325.0 | 0.0 | 465.0 | 1860.0 | 80.0 |
| AT144 | HF Transmitter | 3030.0 | 2440.0 | 29.5 | 560.5 | 18.5 |
| AT144 | HF Transmitter | 3030.0 | 2440.0 | 29.5 | 560.5 | 18.5 |
| MN53B | Marker Receiver | 616.0 | 0.0 | 123.2 | 492.8 | 80.0 |
| MN32A | Multichannel Amp. | 738.0 | 0.0 | 457.0 | 281.0 | 38.1 |
| 180L–3 | Antenna Tuner | 1100.0 | 850.0 | 50.0 | 200.0 | 18.2 |
| MN62A | Compass Receiver | 1825.0 | 0.0 | 365.0 | 1460.0 | 80.0 |
| MN62A | Compass Receiver | 1825.0 | 0.0 | 365.0 | 1460.0 | 80.0 |
| AVQ–9 | Radio Altimeter | 1530.7 | 590.2 | 186.0 | 754.5 | 49.5 |
| R–9/APN4 | Loran Receiver | 1380.0 | 0.0 | 276.0 | 1104.0 | 80.0 |
| 10–6/APN4 | Loran Indicator | 2080.0 | 320.0 | 352.0 | 1408.0 | 67.6 |
| | Total | 29291.7 | 9126.2 | 4165.0 | 16000.5 | 54.6 |

TABLE 5

WEIGHT BUDGET FOR 18 ELECTRONIC EQUIPMENTS FITTED IN A SUPER CONSTELLATION AIRCRAFT BEFORE AND AFTER TRANSISTORIZATION

| Model No. | Description | Before | After | | Savings | |
|---|---|---|---|---|---|---|
| | | Tube lb | Tube lb | Transistor lb | Lb | % |
| 51X–1 | VHF Receiver | 29.4 | 12.6 | 4.0 | 12.8 | 43.5 |
| TA–18B | VHF Transmitter | 42.0 | 13.2 | 2.9 | 25.9 | 61.7 |
| 51R–3 | VOR Receiver | 64.6 | 3.0 | 6.2 | 55.4 | 85.8 |
| 51R–3 | VOR Receiver | 64.6 | 3.0 | 6.2 | 55.4 | 85.8 |
| 51V | Glide Slope Rec. | 31.1 | 7.4 | 2.4 | 21.3 | 68.5 |
| G269 | Public Address Amp. | 21.8 | 0.0 | 1.0 | 20.8 | 95.5 |
| AR144 | HF Receiver | 33.2 | 0.0 | 3.3 | 29.9 | 90.0 |
| AR144 | HF Receiver | 33.2 | 0.0 | 3.3 | 29.9 | 90.0 |
| AT144 | HF Transmitter | 84.5 | 67.5 | 1.7 | 15.3 | 18.1 |
| AT144 | HF Transmitter | 84.5 | 67.5 | 1.7 | 15.3 | 18.1 |
| MN53B | Marker Receiver | 11.6 | 0.0 | 1.2 | 10.4 | 90.0 |
| MN32A | Multichannel Amp. | 17.8 | 0.0 | 7.4 | 10.4 | 58.4 |
| 180L–3 | Antenna Tuner | 18.3 | 14.5 | 0.2 | 3.6 | 19.7 |
| MN62A | Compass Receiver | 54.0 | 0.0 | 5.4 | 48.6 | 90.0 |
| MN62A | Compass Receiver | 54.0 | 0.0 | 5.4 | 48.6 | 90.0 |
| AVQ–9 | Radio Altimeter | 23.1 | 7.8 | 1.5 | 13.8 | 59.7 |
| R–9/APN4 | Loran Receiver | 25.5 | 0.0 | 2.6 | 22.9 | 90.0 |
| 1D–6/APN4 | Loran Indicator | 35.2 | 1.8 | 3.4 | 30.0 | 85.2 |
| | Total | 728.4 | 198.3 | 59.8 | 470.3 | 64.6 |

## ECONOMIC SIGNIFICANCE

Before leaving this subject, it will be interesting to carry these estimated savings one step further and translate them into economics since they can lead to important cost reductions in original aircraft construction. The Douglas Aircraft Company says that it requires 15 lb of cooling equipment for each kilowatt of power consumed by electronic equipment in aircraft[3]. Extra fuel needed by the aircraft per hour to power this cooling equipment is 10.6 lb. Assuming the aircraft has been designed for four hours' flight, the amount of extra fuel to be carried must be 42.4 lb. The total extra weight associated with the cooling of one kilowatt of dissipated electric power is, therefore, 57.4 lb. In the Super Constellation with 1,866.5 watts of unneeded power consumption, the extra load of cooling equipment and fuel becomes 107 lb of dead weight. Now the weight savings possible in the equipment itself constitute another 470.3 lb and the total unnecessary dead weight carried by the aircraft becomes 577.3 lb. With a growth factor of 10, the extra engine horsepower and airframe strength to carry this dead weight will total 5,773 lb. At an estimated cost of aircraft construction of forty dollars per pound, the cost of providing for unnecessary vacuum tube circuits in a Super Constellation can be as high as $231,000, which is about 9.2 per cent of the total cost of the aircraft, taken at $2.5 million. It should be mentioned that four equipments not included in the analysis are also fitted in the Super Constellation under consideration. These are: PB-10 Autopilot, C4 Gyrosyn, Ignition Analyzer and TA150 SELCAL, all of which contain vacuum tubes that could be replaced, or partially replaced, with transistors, making possible even further reductions in original aircraft cost.

## INCREASED RELIABILITY

Important as dollar savings may be in airline economics, the reliability of equipment is even more so. It has not yet been possible to make an effective study of the reliability of transistor circuits through lack of sufficient data, though many estimates indicate that a lifetime greater than 100,000 hours will be normal for transistors in operation. Such long lifetimes put transistors in an entirely different category from tubes, so far as reliability is concerned. From the preceding analysis of the eighteen equipments considered, a full scale conversion would appear to reduce the number of vacuum tubes from 238 to 28. A recent report[4] presented a startling relationship between the complexity of equipment and the mean life of failure-free operation. Using the appropriate curve for commercial airline equipment in this report,[a] the expected failure-free operation for the original equipment using 238 tubes is 50 hours, while that for the transistorized equipment involving only 28 tubes will be 250 hours, the significance of which will not be lost on those concerned with electronic equipment maintenance in aircraft. The same report clearly indicated that operating and maintenance practices are responsible for 36 per cent of equipment failures.[b] It is reasonable to assume that a large part of the maintenance necessary with electronic equipments is due to the large numbers of vacuum tubes used in their circuits. It is argued that the elimination of 210 vacuum tubes or 88 per cent of the total vacuum tube complement for the equipments concerned will materially reduce the amount of maintenance required, and will thus be reflected in an even lower operating failure rate. What is needed, of course, is a direct study of the effect of transistors on reliability, without which it is impossible to analyse the equipment reliability in a formal way, as in the report quoted.

[a]Figure 9, p 17.
[b]Figure 4, p 12.

## CONCLUSION

The following main conclusions are drawn from this analysis:

(1) With present day transistors approximately 88% of vacuum tube circuits could be eliminated from eighteen airborne equipments considered.

(2) The weight and power savings will permit reduction of aircraft construction costs by 9.2 per cent, other costs remaining the same.

(3) Equipment reliability could be boosted from 50 hours to 250 hours mean life between failures.

(4) Silicon transistors, diodes and rectifiers appear to offer the best possibilities for airborne applications.


## ACKNOWLEDGMENT

The compilation of this paper and its preparation for publication was carried out at Computing Devices of Canada Limited, Bells Corners, Ontario, by whom time and facilities were made available to the author for this work. He is also indebted to Mr. B. G. Doutre, Mr. W. Randell, Mr. J. Millar and Mr. J. Hughes of Trans-Canada Air Lines, Montreal, for information supplied by them and used in the paper, and to Mr. C. I. Soucy, R.C.A.F. Air Materiel Command Headquarters, Ottawa, for useful suggestions.


## REFERENCES


(1) Klass, P. – *Vacuum Tubes Face Fast Rising Threat*, AVIATION WEEK, p 50, JULY, 1955.

(2) Klass, Philip J. – *Trend to Transistors Seen Slowed by Military Procurement Policies*, AVIATION WEEK, p 36, AUGUST 1, 1956.

(3) Bull, W. I. (Capt.) – *Future Demands on Component Design*, p 5, PROCEEDINGS ELECTRONIC COMPONENTS SYMPOSIUM, WASHINGTON, D.C., MAY 1-3, 1956.

(4) Soucy, Chester I. – *A Broad Survey of the Military Electronic Equipment Reliability Program and its Controlling Factors*, p 8, PROCEEDINGS ELECTRONIC COMPONENTS SYMPOSIUM, WASHINGTON, D.C., MAY 1-3, 1956.

# C.A.I. LOG

## SECRETARY'S LETTER

**WINNIPEG**

We can all be satisfied, I think, with the first Mid-season Meeting. It was not a very big meeting but no one really expected it to be. Personally, I had hoped to see more members from Vancouver, Edmonton and Cold Lake, since this was after all a "western" meeting. However, the attendance from the east was fairly good.

The introduction of this meeting was something of an experiment and it proved to be a very useful one. We learned a good deal from it which we can apply on future occasions. If any members, particularly from the west, have any suggestions about the programme or the timing or anything else which would improve these Mid-season Meetings, I should be grateful if they would let me know about them.

**I.A.S./C.A.I. MEETING**

In the last issue of the Journal, we issued our first advance notice of the 1957 I.A.S./C.A.I. Meeting. This meeting will be held in Montreal on the 21st and 22nd October.

The dates were originally set in November; they had to be changed. I do not think that we ever publicly announced the November dates but they have appeared in other published calendars and I should like to emphasize, therefore, that the firm dates are the 21st and 22nd October.

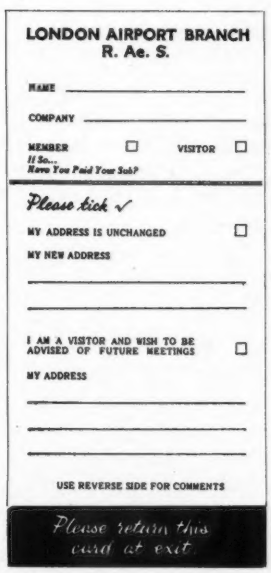
We are working on the programme and details will be published in due course.

**LAPEL PINS**

Every member of the Institute is entitled to wear the C.A.I. lapel pin. I know that some members are unaware of their existence and others do not know how to obtain them. These pins can be obtained from this Headquarters, price $1.00 each.

**FLATTERY**

Members who are in the habit of attending our Branch meetings will recognize a family likeness between our standard lapel card and the card adopted by the London Airport Branch, R.Ae.S. The anglicised version of our card, shown here to half-scale, was sent to me by Mr. B. S. Shenstone, Chairman of the London Airport Branch and, of course, a familiar visitor and speaker at C.A.I. meetings.


LONDON AIRPORT BRANCH
R. Ae. S.

NAME _____

COMPANY _____

MEMBER ☐ VISITOR ☐

If So...
Have You Paid Your Sub?

Please tick ✓

MY ADDRESS IS UNCHANGED ☐

MY NEW ADDRESS

_____

_____

I AM A VISITOR AND WISH TO BE ADVISED OF FUTURE MEETINGS ☐

MY ADDRESS

_____

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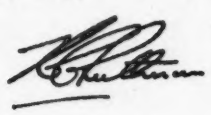
USE REVERSE SIDE FOR COMMENTS

Please return this card at exit

**LIST OF MEMBERS**

We propose to issue the List of Members rather earlier this year and, therefore, the relevant cards have been sent out with the annual dues bills. Please remember that the List is compiled from these cards; if you do not return the card, we have to make one up, using your mail address only; people so often change their jobs, without telling us about it, that their mailing addresses are the only things about them that we know with tolerable certainty.

So please do not fail to complete these cards and send them in, if you want your listing to appear correctly.



# MID-SEASON MEETING

THE Institute held its first Mid-season Meeting in the Fort Garry Hotel, Winnipeg, on the 25th and 26th February, 1957. Hitherto the only major meetings of the C.A.I. calendar have been the I.A.S./C.A.I. Meeting, held in the fall, and the Annual General Meeting, held in May, and these have always been held in Ottawa, Toronto or Montreal. The proposal to introduce a third meeting, to be held this year at one of the western Branches, was regarded with some misgivings; many feared that a meeting, held so far from the concentration of industry in the east and at a time of year when transportation is liable to be disrupted by the weather, would be very poorly attended. However, the meeting was a success and, in view of the rather slender programme provided for the experiment, attendance was all that could have been expected.

The programme comprised an afternoon Session on the 25th February, followed by a Reception and Dinner in the evening and, on the second day, a morning Session and a Plant Tour in the afternoon. The registration for the technical Sessions was 120; 70 went on the Plant Tour; and 195 attended the Reception and Dinner.

The meeting was opened by Mr. J. J. Eden, Chairman of the Winnipeg Branch, who said a few words of welcome before handing over the first technical Session to its Chairman, Mr. T. W. Siers. (Details of the technical Sessions are reported later.) At the conclusion of the second Session, Mr. E. B. Schaefer, Vice-President, closed the formal part of the meeting and expressed the Council's thanks to the Winnipeg Branch for its hospitality and admirable arrangements.

**Mr. J. J. Eden, Chairman of the Winnipeg Branch, opening the meeting.**

### THE DINNER

Reported by N. J. Thomas

Before introducing the Principal Speaker, the President said a few words of greeting to all those attending the Dinner. He paid special tribute to the gratifying growth of the Winnipeg Branch and said that the members from other parts of Canada, and particularly the east, were glad to visit Winnipeg to discuss technical matters of common interest – such discussions were inherent in the objects of the Institute.

He thanked the Sustaining Members in Winnipeg, Bristol Aircraft (Western), Standard Aero Engine and Imperial Oil, for their active participation in the meeting and for the Reception which had preceded the Dinner.

In reference to the growth of the Institute, the President said that the membership now exceeded 1,900, with sufficient applications in process to raise the figure to 2,000 before long. He also mentioned the Journal and gave credit to G/C Foottit for the establishment of this publication, which was attaining recognized standing in its field and performing a very useful service to the members of the Institute.

He then called on Mr. Eden, Chairman of the Branch, who read a telegram of greeting received from Mr. Juba, Mayor of Winnipeg.

The President then introduced Mr. S. H. Deeks, Executive Director of the Industrial Foundation on Education, the Principal Speaker of the evening.

Mr. Deeks' talk, entitled "Chinks in our First Line of Defence", pointed out that one of the country's greatest weaknesses is the shortage of trained personnel to carry out the technical requirements of modern defence systems and to supply the cultural background necessary for lasting peace and prosperity. He emphasized the desirability of a balance between a technical and a liberal education, although this would increase the demands on the educational system and necessitate the training of a larger percentage of the high school graduates than in countries like Russia, where much greater emphasis is placed on purely technical forms of education. Mr. Deeks felt that Canada was already falling behind in numbers of technically educated people. On a per capita basis, Canada is training only 25% of the numbers trained in Russia and 35% of the numbers trained in the U.S.A. In fact, Mr. Deeks stated Canada is training only 20% of those capable of higher learning. This is insufficient to provide his estimated requirement of 60,000 engineers and technicians, in the face of increasing migration of trained personnel to the U.S.A. and decreasing emigration from Europe.

Having described these shortcomings of the educational system, Mr. Deeks went on to outline some of the steps necessary to fill these "chinks in our first line of defence". He said that proper recognition and accreditation of technicians would help the training program and provide valuable assistance for the engineers and scientists.

Mr. Deeks thought that organizations like the C.A.I. could help coordinate

**The Principal Speaker, Mr. S. H. Deeks**

**Part of the Head Table at the Dinner: (l to r) J. J. Eden (Chairman, Winnipeg Branch), E. B. Schaefer (Vice-President), T. E. Stephenson (President), S. H. Deeks (Principal Speaker).**

**Intermission time**

existing training facilities, such as schools, universities, plant training and technical high schools, by establishing nationally recognized standards and by drawing public attention to the need.

In conclusion, Mr. Deeks warned that if we are to enjoy our present level of prosperity and security, clear and decisive action of all citizens will be required lest we be weighed and found wanting.

Prof. C. M. Hovey thanked Mr. Deeks for his clear and searching analysis of technical education problems and wished him every success in his efforts to solve them.

## TECHNICAL SESSIONS

The following reports on the technical Sessions have been submitted by members of the Winnipeg Branch.

### Afternoon Session, February 25th

### Maintenance and Overhaul

Reported by D. W. Clifford and A. Soroka

Mr. T. W. Siers, Assistant to the Director of Maintenance and Engineering, Canadian Pacific Air Lines, was in the chair. He opened the Session by announcing that the paper originally to be presented by Mr. G. W. Northcott and Mr. S. G. Marsh of TransAir Limited had been withdrawn and it had been assumed that it would be dropped from the programme. However, Mr. Marsh had, in fact, submitted a paper at the last moment and, since he was unable to be present, Mr. A. S. Jackson had agreed to read it.

The paper was entitled "Aircraft Maintenance in Extreme Low Temperatures". (Mr. Marsh is Maintenance Supervisor of TransAir Ltd. and is at present stationed at Churchill.)

Effects of low temperatures on the operation of the aircraft and methods used to combat these effects were covered in some detail. It was pointed out that engines "cold soaked" in temperatures in the range of −35°C and below required pre-heating regardless of the fact that oil dilution may have been used. Mr. Marsh also noted that although oil dilution may be used to advantage in temperatures as low as −35°C, in temperatures ranging below this figure, if it is used at all, it is to be used with extreme caution. The reason caution is necessary is due to the fact that, in these extreme temperatures, the oil temperature seldom becomes high enough to "boil" the fuel out of the oil. Continued dilution without this "boil-off" results in deterioration of the oil to the point where engine failure can result.

Mr. Marsh covered all the major units and components of the aircraft, giving the effects of cold weather on each. It appears that the most consistent cold weather problems can be attributed to the various types of seals used throughout the aircraft. Hydraulic seals become brittle and cause leaks. Oleo seals in the landing gear leak for the same reason and cause considerable hardship and delay due to the limited hangar and equipment facilities at northern stations. Door seals become hard and make it difficult to open or close cargo and compartment doors etc. These were all major contributors to expensive delays.

Mr. Marsh concluded his paper with the request to aircraft manufacturers to consider the northern operator during the design stage and noted that the majority of cold weather problems associated with modern aircraft are the same problems that northern operators have been contending with since the beginning of arctic flying.

The second paper of the Session, "Ground Servicing Equipment in Cold Weather Operations", was given by S/L R. Sloat, Chief Project Engineer, CEPE Climatic Detachment, Namao.

S/L Sloat covered modifications and techniques that are necessary when operating ground equipment, servicing and maintaining aircraft in −45°F weather. Piston engined equipment gives the most trouble. Auxiliary heat, a 12 v start for a 6 v system, heated batteries, special high volatile starting fuel and reduction of heat loss during running were mentioned.

Hydraulic equipment and jacks require cold weather seals the same as airborne equipment.

The operation of lubrication oil tenders has been a problem because of the heavy grades of oil handled. Heated tanks and delivery hoses are required. The design of the heat exchanger for the oil tank is important to avoid damage to the oil from excessive local heating.

The design of all equipment, particularly fuel servicing equipment, should allow for the fact that the user will be required to wear heavy clothing and mitts and to cope with snow and ice.

Aircraft maintenance is made much easier if the mechanics can be sheltered from the wind and some heat provided. For small jobs, portable electric heaters have been used and, for larger jobs, the familiar Herman-Nelson.

The use of covers to keep out snow was discussed. Wing covers are not practical on aircraft over 50 ft in span. Often it is easier to blow snow away than to provide a cover to keep it out. It is important to blank off openings in engine cowlings. An access hatch may be provided for the Herman-Nelson hose.

**Maintenance and Overhaul Session: (l to r) R. J. Proctor, T. W. Siers (Chairman), S/L R. Sloat, A. S. Jackson.**

S/L Sloat illustrated his talk with slides showing various items of equipment used and developed at Namao. Defrosting equipment with long nozzles and large operating valves enabled personnel to spray surfaces from stands. Ladders were used with a pattern of spotwelds on the rungs to provide better footing. Mobile equipment with large wheels for snow was a necessity. A point brought out was that towing loads in snow were much higher and nosewheel towing was not advisable in such cases.

S/L Sloat closed his talk by emphasizing that delays from inadequate or unserviceable ground equipment were just as costly as delays caused by aircraft unserviceabilities. He asked that equipment manufacturers pay more attention to winter requirements.

"Overhaul and Maintenance of Commercial Aircraft" was the title of a talk given by Mr. R. J. Proctor, Manager, Air Service Department, Northwest Industries Limited.

In Mr. Proctor's opinion, the servicing and maintenance of large, modern aircraft, for operators flying in remote areas where maintenance and overhaul facilities are inadequate, is most economically and satisfactorily handled under contract to a servicing company such as Northwest Industries.

Mr. Proctor cited an example of a northern operator who, having transferred its major check work to an overhaul contractor of this type, was able to reduce the airline servicing staff from 15 to 6. Although the ferrying of aircraft to the contractor entailed some inconvenience, the economy achieved and the increased serviceability, in Mr. Proctor's opinion, far outweighed the ferrying costs involved.

It was also pointed out that these overhaul companies are equipped to carry out manufacturers' modifications or conversions and have facilities for salvaging damaged aircraft in remote areas. Slides depicting various salvage operations were shown.

**Morning Session, February 26th**

**Safety and Survival**

Reported by L. S. Styrczula and A. R. Hunt

On Tuesday morning, a talk entitled "Survival Training of the R.C.A.F." was given by F/L R. J. Goodey, Officer i/c Arctic Detachment, School of Survival Training, Cambridge Bay. F/L Goodey was introduced by the Chairman of this Session, G/C J. R. Frizzle, CO R.C.A.F. Station Namao.

F/L Goodey opened his talk by stating that the object of the survival training school, operated by the R.C.A.F. in Edmonton, was to provide knowledge and assistance to the men who fly the north. The training enables a downed airman to survive in this "frightful area to the uninitiated" during the time he is being searched for.

The school, in nine years of operation, has not lost a student. There are five days of instruction at the school followed by eleven days of actual bush work at nearby Jasper and then a return for six days into the Arctic. The students are taught the importance of knowing about weather over the tundra, to know where to expect habitation, what safety equipment is required and how to use it effectively. They are taught how to build a shelter, light a fire, signal searching aircraft and how to find and use food and water.

With the talk, a film "Arctic Training in the Tundra" was shown. One of the more interesting highlights was the building of an igloo. The film also showed how to live in an igloo, how to prepare ground signals to aid searchers, how to catch a fish through six feet of ice and how to make a ptarmigan edible.

F/L Goodey extended an invitation to any who may be in the Edmonton area to visit the interesting array of survival and related equipment the R.C.A.F. has on display there. Questioners after the talk showed their interest in what the ptarmigans subsisted on during the winter and in the minimum survival period, assuming the downed airman had nothing more than the survival kit provided. F/L Goodey stated this should be eleven days. The equipment included in the survival kits was discussed at some length.

The talk by Mr. D. N. Campbell, Supervisor and Chief Pilot, Saskatchewan Air Ambulance Service, entitled "The Saskatchewan Air Ambulance Service—Technical and Otherwise", described problems surmounted during the eleven years since the service was started. This service, which carries the patient to the facilities, is unique, although a similar service exists in Australia where the doctor is taken to the patient.

Originally, the Air Ambulance Service had one Norseman, one pilot and one air engineer. For a time a Fairchild Husky and a second Norseman were in service. It now has two twin-engined Beechcraft 18's and four Cessna 195's. Despite accidents resulting in serious aircraft damage, no passenger or crew member has ever been injured.

Operations include trips to remote areas of Saskatchewan to pick up emergency cases and trips outside the province to deliver critically ill patients for specialized treatment.

The Cessnas were chosen because their tail heavy c.g. location and strong undercarriage seemed suited for operation on soft and rough fields and because they had good cruise, takeoff and climb performances. However, considerable fuselage reinforcement has been found necessary because of the rough fields often used.

Soft fields have been a problem. It is sometimes necessary to partly deflate the tires to increase their contact area and so keep the aircraft on the top of soft ground. It is remarkable that there are only two weeks during the spring breakup that the service cannot carry on.

All pilots of the service hold transport licenses including instrument ratings. It has been found necessary, however, to make most flights under Visual Flight Rules, even in adverse weather. Frequently the only references the pilot has in a grey sky and grey snow surface are railway lines and telegraph poles.

The Air Ambulance aircraft are maintained at their Regina base. Complete overhauls are done on the Cessna 195's. All aircraft are modified to carry oxygen equipment and the special medical kits required by the attending nurses. There are also interior changes to accommodate the special airborne stretcher.

Mr. Campbell's talk on this Air Ambulance Service was in considerable detail and gave his audience a remarkably clear insight into the operation and special requirements of an air ambulance service.

At the conclusion of his talk there was a question and answer period during which the following points were raised by members of the audience:

(a) Mr. Campbell was queried as to whether or not the British Auster aircraft had been considered for this air ambulance work. His reply was in the affirmative but they had decided not to purchase this type of aircraft since they were anxious to maintain standardization with their powerplant as far as possible to permit usage of American-type hand tools which can be used on both the Beechcraft 18 and the Cessna 195.

(b) Mr. Campbell was also queried as to whether or not they had found JATO useful on the Husky aircraft. He replied that, while they had used JATO occasionally and had found it very effective, they did not find it desirable to use this facility while carrying patients. This limitation stemmed from the fact that when JATO was in use, it was necessary to climb the aircraft very steeply to control speed and this manoeuvre was found too violent with sick or injured persons aboard.

**Safety and Survival Session: (l to r) F/L R. J. Goodey, G/C J. R. Frizzle (Chairman), D. N. Campbell.**

**Afternoon of February 26th**

**Plant Tour**

Reported by L. S. Styrczula

Standard Aero Engine Limited was the first plant visited. The welcome card presented to all the guests states that "Standard Aero was formed in 1937 and, at that time, consisted of a small shop and a handful of employees. Since then the Company, like the industry itself, has steadily progressed. The modern plant at Stevenson Field in Winnipeg contains over 60,000 square feet of floor area and is equipped with the most modern tools and test equipment available."

What the welcome card omitted to say was that the modest exterior of the plant might mislead one about the inside. The interior can be compared to that of a hospital for neatness and orderliness. There is an obvious air of efficiency about the entire plant. There were many favourable comments on this and the stuffed sailfish that keeps a watchful eye on the engine overhaul section!

Overhauls are made on engine, accessories and ground equipment. Types of engines overhauled include those of Pratt and Whitney, De Havilland, Lycoming, Franklin, Continental, Warner and numerous types of diesels.

Approximately 300 types of accessories are handled. Some of the ground equipment overhauled include snow blower diesels, gasoline driven energizers, several forms of rectifiers and the odd power package for G.C.A. equipment.

The plant tour of Bristol Aircraft (Western) Limited, a 442,000 sq ft plant, was the last item on the agenda. A wide variety of aircraft types pass through the plant, the most prominent features being the CF-100 modification line, the Expeditor CAIR line and Mitchells belonging to the R.C.A.F. Winnipeg. The Company has the exclusive manufacturing rights in Canada for standard and amphibious floats for De Havilland Beaver and Otter aircraft and a surprisingly large number of these floats were being made. Another interesting item was the "hot end" components being manufactured for the CF-100, to a very high standard of workmanship. In the reception room, there was a scale model of the Britannia. Unfortunately the real thing, which had been in Winnipeg until two days before, had been withdrawn from the programme when it had to leave unexpectedly for Vancouver.

After a look at these extensive facilities, many of them busy at the time, the tour wound up with a much appreciated cup of coffee.

# BRANCHES

## HALIFAX-DARTMOUTH BRANCH

THE Branch formerly referred to as the Halifax Branch will, in future, be known as the Halifax-Dartmouth Branch, in accordance with the wishes of the Branch, as approved by the Council.

Furthermore, Professor O. Cochkanoff has relinquished the office of Secretary of the Interim Executive Committee and has been replaced by Mr. H. S. McCaskill. Mr. McCaskill's address is

P.O. Box 164,
Shearwater, N.S.

Professor Cochkanoff has "held the fort" for a long time and the formation of the Halifax-Dartmouth Branch is a tribute to his service.

## CALGARY

Mr. J. D. Zmurchyk has taken over the post of "Interim Secretary" in Calgary, succeeding Mr. W. E. Jamison. Mr. Zmurchyk's address is

1941–25 Ave., S.W.,
Calgary, Alta.

Mr. Jamison has shown great interest in the Institute from its very early days and still retains his membership of the Alberta Committee on Education and Training. While he has been Interim Secretary in Calgary, the membership has steadily increased – it is now 18, with enough applications pending to carry it over 20, the minimum requirement for the formation of a Branch.

## NEWS

**Toronto**–Reported by W. T. Heaslip

*First February Meeting*

A special meeting of the Toronto Branch was held on February 4th at which the Chairman, Mr. F. H. Keast, called on Mr. F. H. Buller to introduce the speaker.

In introducing Mr. H. C. van Meerten and his subject, "The Design and Development of the Fokker Friendship", Mr. Buller applauded the energy and aggressiveness of a small country like Holland in undertaking such a comprehensive job with comparatively limited resources.

In his opening remarks, Mr. van Meerten also touched on the problems which smaller countries, such as Canada and Holland, have in complicated engineering projects and pointed out the success that had nevertheless been achieved in many Canadian projects and the Friendship project as exemplified by the manufacturing of this aircraft in the United States.

In developing the background for the design of the Friendship, the speaker pointed out that the Fokker Company had confined itself in the post-war period to the design and manufacture of trainers, waiting for a chance to enter the civil field. In 1950, it was decided to embark on a Dakota replacement because extensive surveys indicated that the majority of continental traffic was carried by Dakotas and that current new designs left a very large gap in the 20-35,000 lb size. The surveys led to an airplane carrying 32 passengers in a pressurized cabin over a 300 mile range which, in spite of high initial costs, would make it very competitive with the Dakota in this field because of the low operating costs.

After establishing the need for the aircraft, the most important point was the choice of powerplants and, in this choice, both jets and turboprops had to be considered along with conventional engines. Over the ranges considered, the turboprop was by far more economical than the pure jet and in considering an aircraft powered by reciprocating engines, giving the same payload and range characteristics, it was found that the powerplants would weigh some 3,600 lb more and the cruising speed would be reduced from 275 mph, as achieved with the turboprop Darts, to 245 mph. The Dart installation was also found to give a 20% reduction in the cost per ton mile, but with a sacrifice of a lower maximum range.

In discussing structural features, Mr. van Meerten pointed out that a Redux system was used extensively on the F-27 in line with the excellent experience they have had on their trainers. This system gives far better fatigue and cost factors in combination with better contour and structural stability control. He also commented on the use of laminated plastics which were used extensively for secondary structures and complicated shapes. The fuselage nose section and nosewheel doors are excellent examples. He also pointed out the liberal use that had been made of 75ST forgings which he felt resulted in great savings of parts and complexity.

In touching on the pneumatic system, Mr. van Meerten noted that they were the first to use a 3,000 psi pneumatic system which they had chosen because of low fire hazard, low weight and high speed of operation. Its use on landing gear retraction, anti-skid brakes and nosewheel steering has proven entirely satisfactory, except for a difficulty encountered in steering under high side load conditions which has been solved by redesign of the steering actuator.

The speaker discussed at some length the correlation between wind tunnel results and performance estimates and the actual values achieved. Wind tunnel data was excellent when compared with full scale, except in the case of control surface hinge moments. On the performance side, lower stalling speeds than estimated resulted in better landing and takeoff characteristics and the drag figures proved to be only about 20% greater than an absolutely clean aircraft.

Mr. van Meerten touched briefly on the current status of the project, indicating that official C. of A. testing was in progress and that the second prototype, after having had the fuselage completely water tested, was now ready. A fatigue testing program is also under way on another prototype. Concerning delivery schedules, it was indicated that first production deliveries from Holland are expected in May, 1958, with production from the United States expected somewhat earlier.

In conclusion, the speaker gave some indication of the expenditures involved up to the completion of four prototypes. These were roughly £2,000,000 overall cost, which was made up of 650,000 engineering man-hours, 1,400,000 man-hours of building time and 1,000,000 man-hours devoted to tooling.

At the conclusion of a brisk question period, during which a number of points concerning the construction and the operation of the Friendship were discussed, the speaker was thanked by Mr. I. M. Hamer. Mr. Hamer remarked that, when so much time is spent on military aircraft working with unlimited budgets, it was a pleasure to hear about a first-class replacement in the civil field. He commented on the suitability of the Fokker firm for such a job, noting their long association in the aircraft business, a comment which also applied to the Fairchild firm which had accepted the license to build them in America.

*Second February Meeting*

Reported by Professor T. R. Loudon

The second February meeting of the Toronto Branch was held on the 20th February at 8.30 p.m. in the De Havilland Aircraft of Canada cafeteria.

Mr. C. N. Lucas of Avro Aircraft Limited addressed the meeting of some 80 members on "Procurement Problems in Modern Aircraft Production".

The speaker gave a very interesting explanation of the necessity for a procurement group in a plant to insure that all phases of any product were investigated free from any personal prejudice before a purchase was recommended. He gave examples of the difficulty of resolving the claims when several different departments have firm ideas about equipment.

One great problem was to see that inventory did not become too great but, at the same time, to insure that the supply of much needed items did not suddenly dry up.

It was interesting to hear that the Avro procurement department was operated with fewer personnel per unit of employees than some of the larger United States firms.

The question period brought out many problems which those in the industry recognized as perennial. The speaker gave very convincing answers to all queries.

Mr. Lucas was given a hearty vote of thanks moved by Mr. J. F. Taylor of Bendix-Eclipse of Canada Limited.

**Cold Lake**–Reported by R. W. Ellard

*February Meeting*

The February meeting of the Cold Lake Branch took place in the library of the Sergeants Mess at 8 pm on Wednesday, February 13th. S/L R. G. Christie, Branch Chairman, introduced the guest speaker, Mr. Carl Agar of Okanagan Helicopters Ltd.

Mr. Agar traced the development of Okanagan Helicopters and described its connection with the Kitimat Project in British Columbia. In his own inimitable style, he explained how his world-famous mountain landing technique was evolved and went on to describe the many roles for which the helicopter was particularly useful – and in some cases indispensable.

Mr. Agar's talk was followed by a film on Bell Helicopter operations during the Kitimat Project, which brought home to the membership the fantastic nature of the flying which he had been carrying out. Mr. Agar is obviously a very modest man!

W/C R. D. H. Ellis thanked the speaker and an active question period followed during which refreshments were served. 35 members and guests attended the meeting.

*March Meeting*

A mixed informal meeting was held on the 5th March when members invited their wives to see two films, "History of the Helicopter" (Shell) and "The Man with a 1,000 Hands" (International Harvester – Kitimat Project). About 45 persons attended and a "good time was had by all".

**Ottawa**–Reported by S/L W. M. McLeish

*February Meeting*

The Ottawa Branch held its February meeting on Wednesday, the 13th, in Beaver Barracks. The attendance was unusually small, 28 members and guests, and resulted from two military events on the same evening from which C.A.I. members could not excuse themselves.

The guest of the evening, Mr. C. I. Soucy, is in charge of Electronics Engineering Control at Air Materiel Command Headquarters. He presented a paper on the "Reliability Control of Electronics Equipment in Aircraft and Weapons Systems" and was introduced by Mr. Z. W. Sametz, Statistical Analyst at AMCHQ. Mr. Sametz reviewed Mr. Soucy's experience in the reliability field and stated that the speaker is an international leader in this work. Mr. Soucy's material and presentation provided the Ottawa Branch with more than enough evidence to support Mr. Sametz's comments.

Mr. Soucy dealt primarily with the management aspects of the subject and he was quick to point out that the topic has often been over-simplified, which has led to technical misconceptions and has retarded progress in the reliability field. To avoid over-simplification, Mr. Soucy indicated that he would discuss a few selected highlights of the topic to establish "the philosophy that the attainment of the reliability goal requires a new way of thinking and is of vital concern to management". The disparity between present performance and desired goals is not hopeless; it will be bridged through the persistent application of engineering systems analyses, of which reliability control is the key. The profit motive spurred the commercial fields to seek out an understanding of reliability control and, although the military have many more complications to cope with, there is good indication that the influence of missile reliability control will be extended to the other aspects of military systems.

Mr. Soucy defined reliability as "the probability of a device performing its intended function adequately for a designated period of time (without repair or corrective maintenance) under the operating conditions encountered". Following the definition, the topic was dealt with under the following headings:

(i) Economics of reliability control
(ii) Complexity and time factors
(iii) Critical complexity, reliability barriers and adequacy of improvement goals
(iv) Evaluation of reliability
(v) Analysis of claims re failure causes
(vi) Maintenance environment and usage factor
(vii) Basic need is better design
(viii) Procurement bottlenecks
(ix) Reliability organization.

Mr. Soucy carefully tied these steps together to provide good continuity to the "new way of thinking". He used some excellent examples from the commercial and military fields to illustrate each step and made frequent reference to a series of slides.

The lecture was followed by an equally interesting question period which threatened to last indefinitely, but the Chairman, Mr. M. S. Kuhring, was obliged to call upon G/C R. M. Aldwinckle to thank the speaker and adjourn the meeting: it was 11 pm.

*March Meeting*

The eighth meeting of the Ottawa Branch was held on Wednesday, 13th March, at Beaver Barracks. The Branch Chairman, Mr. M. S. Kuhring, announced the names of the members comprising the Nominations Committee, under the leadership of G/C D. M. Holman, and indicated that the nomination notices would be in the mail about the 25th March. Upon receipt of the returns from the members, the ballots will be mailed and it will be requested that all ballots should be returned not later than the 29th April. A special meeting will be announced for mid-May to allow the new Executive to take office prior to the Institute Annual General Meeting. However, the present Executive will shoulder the load of the Institute Annual General Meeting which is to be held in Ottawa this year.

The guest speaker of the evening was Mr. F. W. Lowry of Westinghouse Electric Corporation, Ohio. Mr. Lowry is the Assistant Sales Manager, Aircraft Equipment, and has been associated with aircraft electrical development for twenty years. His paper, entitled "New Equipment for AC Power Systems", was extremely informative of the future trends in aircraft electrics.

Mr. Lowry has recently been appointed to the task of estimating the aircraft and missile electrical requirements for the next decade and in his

paper he gave many hints, within the limits of security, of the design trends in the U.S.A.

In his opening remarks, he briefly mentioned the electrical installations of World War I aircraft and traced the evolution of present day electrical systems. The DC systems which have been the backbone of most World War II aircraft are no longer adequate and, in emphasizing this point, Mr. Lowry briefly described the AC system employed in the B-47. This aircraft utilizes standby equipment and control computers to achieve reliability. For example, a standby generator can be automatically put into service, in the event of main AC generator failure, in a few seconds. The computers constantly analyze the circuits and then either warn the crew of a system failure or select the standby equipment. Installations of this type enable the B-47 to be manned by only three crewmen and to carry out complex operations over long ranges at high altitudes. The B-52 has similar more advanced equipment.

The success of these systems is based on the ability of the electrical manufacturers to develop and produce brushless oil-cooled generators of high power and low weight, plus similar advances in rectifiers, amplifiers etc. The utilization of transistors and the associated "OR", "AND" and "ADD" circuitry has greatly reduced both weight and power loss. The control of power loss in the form of heat represents an enormous advance because supersonic aircraft will require cooling systems of 10 to 40 lb per watt of electrical heat to control the heat sinks.

Mr. Lowry indicated that the B-47 method of achieving reliability would continue in man-carrying aircraft because the prime mission is to see the crew home safely. On the other hand, missiles must achieve reliability from each component part of the system; hence the components are subject to more serious reliability control procedures.

Finally, after presenting a film dealing with the systems aspects of electrical designs, Mr. Lowry stressed the fact that all future development work must be achieved via systems analyses in lieu of the current methods in which the power supply, reliability control and utilization are dealt with in their own environments. The result should be power packages concentrated in specific parts of the aircraft, integrated with computer controls and heat exchangers and much less wiring and energy loss. The impact of these requirements on the associated sciences of metallurgy, plastics, ceramics, mechanics, petroleum and systems analyses has already been felt and will necessitate expenditures in research, production and operational training heretofore unknown.

G/C Limbrick thanked Mr. Lowry after a brief question period and the meeting adjourned at 11.00 pm.

**Vancouver**—Reported by R. J. McWilliams

*February Meeting*

For some time now there have been murmurings from our better-halves, for example, "what do you do each month at C.A.I.?" and "do you really enjoy listening to those dry old speakers?" Well, there was only one way to answer them — put on a regular meeting for both members and wives and/or members and husbands. And they lapped it up; the meeting was a huge success! Quite the best attended meeting we've had this year with no fewer than 125 people present. Of course we cheated a little as the speaker for the evening was first-rate; Dr. Gordon Shrum, Head of the Physics Department, University of British Columbia.

The subject of the talk was "The Impact of Atomic Energy on Transportation". The emphasis was placed on the impact, with transportation as a side line. This reflected the excellent judgment of the speaker since it met both the taste and the mood of the mixed audience. Having illustrated the tremendous resources of power in the atom, Dr. Shrum spoke of the dwindling reserves of coal and oil and of the spiralling rise of the world's population. Canada's natural resources assure her of a leading role among the nations of the world, a role which brings with it heavy responsibilities in raising the standard of living of less fortunate nations. To realize this future, we must start now to ensure that trained personnel, scientists and technologists will be available. Neglect of the sciences in Public School and High School must stop and we must make better use of the mental ability of the ladies.

Dr. Shrum spoke for an hour and had the complete attention of his audience. The gravity of his theme was more than adequately compensated by his lively sense of humour. His down-to-earth approach and his ability to put across a point in layman's language set an example to which all "technical" types should aspire.

After a short discussion period, our speaker was thanked by Mr. H. D. Cameron and the meeting adjourned for coffee and sandwiches and the usual chinwag.

*March Meeting*

Reported by I. A. Gray

A joint meeting was held with the Society of Automotive Engineers Vancouver Chapter and the Canadian Aeronautical Institute Vancouver Branch on the 11th March at the Georgia Hotel. After the usual dinner festivities, a technical audience of 125 persons was addressed by Mr. C. E. B. McConachie, Technical Assistant to the Vice-President of Operations, CPAL, on the subject, "Free-Piston Engines".

In the past, these joint meetings have been devoted exclusively to aircraft and the C.A.I. took this opportunity to provide the local S.A.E. membership with a subject of unusual interest. The majority of the local S.A.E. members are directly concerned with automobile and marine applications of internal combustion engines and the free-piston engine promises to be very important to them in the near future.

The speaker was extremely well qualified, having done the original research on this type of engine at Stanford University.

Mr. McConachie gave a general description of the engine, its basic theory and operation, amply illustrated so that the layman had a general conception of the machine within a few moments.

The free-piston engine was developed thirty years ago in Germany and France. It was used originally as an air compressor; the Germans used these machines to charge torpedoes during World War II.

It was later developed as a "gasifier" which produces gas to drive a turbine and it is in this direction that current development is being directed.

As a gasifier, it has several favourable characteristics:

(1) A relatively cool gas is produced.
(2) The cool gas means that readily available materials can be used with common and well-proven production machinery.
(3) The initial cost price should be very reasonable.
(4) Very easy maintenance due to the elimination of bearings and other complexities of the conventional internal combustion (crank) engine.
(5) Reasonable weight and cost per horsepower.
(6) No vibration and, therefore, no shock mounts or other special installation techniques are necessary.
(7) High torque available.
(8) Power can be increased by a simple re-heat or afterburner.
(9) Burns anything from whole oil to 115/145 high octane aviation gasoline.
(10) Thermal efficiency of 32-38%.
(11) Minimum friction.

The engine has its problems, one of the toughest being lubrication under

high temperature and pressure. The pressure ratio can be as high as 40:1 and the fuel is burnt at what might be termed the point of 'controlled detonation'.

The high temperatures are indicative of a difficult heat transfer problem.

Mechanically there is very little to go wrong with the engine and the only accessories are a fuel ignition pump and a coolant pump. It is started by an air charge from a storage cylinder.

Mr. McConachie closed his talk with the showing of a G.M. film describing their Hyprex engine. G.M. have a license agreement with the French and have produced a development engine for a very futuristic automobile.

Following an interesting discussion period, the speaker was thanked by Mr. H. Welch, S.A.E., and the meeting was adjourned.

**Montreal**—Reported by
W/C C. R. Thompson

*February Meeting*

The Montreal Branch of the C.A.I. held a joint meeting with the Montreal Chapter of the S.A.E. on the 18th February, 1957. Mr. W. K. Ebel introduced the speaker, Dr. A. C. Johnson, Manager of the Nuclear Division of Canadair, who gave a talk on "A Progress Report on Nuclear Power".

In his talk, Dr. Johnson stated that, particularly in nuclear energy projects, it is essential to bring the scientist and the engineer together as a team. For instance, the physicist developed a 25 billion electron-volt machine which had a magnet weighing over 4,000 tons, with an orbit diameter of 800 ft and with a pulse power of 37 megawatts. The engineer had the problem of applying this power.

Dr. Johnson then showed the possibilities from nuclear fission and fusion processes and traced the history of their development from the first controlled reactor built by Fermi in Chicago in 1942. He then described what had been done in Canada in developing nuclear reactors, including Zeep, NRX and NRU. He showed comparative figures on the costs of these powerplants compared with coal, oil or water-powered plants.

The speaker discussed some of the engineering problems which had been encountered, such as the handling methods necessary with radiating material, the high pressures required in heat exchangers, the thick shells which had to be welded and so on.

In conclusion, Dr. Johnson said that at present it was an anomaly that in the United States the greatest consumer of electrical power was the atomic energy program, but it was expected that by 1965 nuclear power will be one of the conventional methods of electrical power production.

After the talk, two beautiful colour films of Britain's Calder Hall project were shown. One film showed the atomic energy aspects of the project, while the other dealt mainly with the civil engineering problems.

The question period brought out the information that only one-third of 0.7% of natural uranium was burned in a nuclear reaction. In answer to a question on the atomic submarine, it was pointed out that military and other considerations reduced the safety factor on the submarine as compared with land based reactors. The cost of accidents was questioned. It was stated that a lot had been learned from various accidents which showed that it was possible to handle normal "spillage". The speaker was thanked by Mr. T. A. Harvie.

# SUSTAINING MEMBERS

## NEW SUSTAINING MEMBERS

THE following Companies have joined the Institute as Sustaining Members:

**Enamel & Heating Products Limited**

**Collins Radio Company of Canada Limited**

## AIRCRAFT NAMES

It has been announced recently that the names Arrow and Argus have been selected for the aircraft previously known as the Avro CF-105 and the Canadair CL-28 or CP-107 respectively.

## NEWS

**ElectroData Division of Burroughs Adding Machine of Canada Ltd.** has announced an expansion of its facilities to provide sales, technical and field engineering service in Ontario, Quebec and the Maritime provinces. The Company is responsible for the sales, rental and servicing of the Datatron electronic data processing systems, the Burroughs E101 desk-size digital computer and the G101 high-speed printer. To date two Datatron computer systems have been installed in customers' plants in Canada and one Burroughs E101 is available for demonstration purposes.

**Minneapolis-Honeywell Regulator Company Ltd. and Computing Devices of Canada Ltd.** have been selected as subcontractors for the engineering services relating to the electronic weapon system of the Avro Arrow. The system is under development by the Radio Corporation of America and the Minneapolis-Honeywell Regulator Company in the U.S.A.

The subcontract awards are in connection with a research and development contract for the Arrow's electronic weapon system awarded RCA last fall by the United States Air Force, on behalf of the Canadian Department of Defence Production. The USAF contract assigns to RCA full responsibility for the development of a complete electronic system for fire control, navigation and communication and an integrated automatic flight control system. Honeywell's Aeronautical Division is working with RCA on an associate basis, with responsibility for the development of the automatic flight and other system controls.

Computing Devices of Canada Ltd. has been awarded a subcontract in connection with the development of an automatic Dead Reckoning Navigation system, which will be integrated with the electronic weapon system. The navigation system automatically will advise pilots of their distance from target or base and of required courses to reach specific destinations.

CDC has had extensive experience in the development of automatic Dead Reckoning Navigation systems, having pioneered in this field with the well-known Position and Homing Indicator. More recently, CDC was awarded the contract for the Navigation system for the RCAF's new Maritime patrol aircraft, the Argus.

Honeywell Controls Ltd., a subsidiary of the Aeronautical Division of the Minneapolis-Honeywell Regulator Co., employing approximately 1,000 people in Canada, has been entrusted with the engineering services in connection with the development of automatic flight controls.

**Field Aviation Company Ltd.** is installing airborne Shoran equipment in a B-17 in preparation for the Photographic Survey Corporation's forthcoming mapping expedition in the Arctic. P.S.C. has been awarded a contract to continue the Government's Shoran-controlled survey of Canada's northlands, which was begun in 1947 by the Canadian Geodetic Survey. All of Canada south of the Arctic coastline has been filled in with a geodetic net of accurate ground positions established by Shoran methods with supporting photography of the area. It will be necessary to establish several secondary Shoran base stations within the geodetic net to assure accurate positioning of the photographic exposures.

A B-17 will be used for the first time in a survey of this type in Canada. Supporting it will be a Canso amphibian for bringing out the crews and equipment after the ice break-up; a DC-4 for airlifting the personnel and materiel to Foxe Inlet on Melville Peninsula in May; and a DC-3 to relay them to eight Shoran sites, all of which will be occupied simultaneously. The personnel at these sites will have 10 weeks food supply with them when the camps are set up. There will be a period during the ice break-up, which may occur in this region in June, July or August, when the camp sites will be inaccessible except by helicopter and then only by relay stages from the nearest airport. The ski-equipped DC-3 or a Canso amphibian will be used for supply depending on conditions. However, the existence of soft or broken ice in adjacent lakes may prevent the use of either. It is not uncommon for ice to change from a safe landing surface to a mass of jumbled ice floes in two or three days. Food can then be dropped if the break-up prevents the supporting aircraft bringing supplies to those station crews which are obliged to stay beyond the period for which food is supplied.

Base of the expedition will be an airstrip at Foxe Inlet which is north of Hudson Bay and some 2,000 miles due north of Toronto. At Foxe the photographs taken on day-to-day flights at heights up to 28,000 ft and spaced at intervals of approximately 20 miles, will be processed and then inspected by a Government official. Film processing will be done at Foxe and the film will be forwarded as frequently as possible to Toronto where copies on glass plates will be made in the laboratories of P.S.C. The unit at Foxe, however, must be self-contained so that processing, checking of data, plotting and decisions of reflights can be carried out on location.

The operation airlift begins in early May with the actual photography starting about the first of June when enough ice melts off Baffinland to make photography practicable. Snow falls throughout the year in this region. Only for a few months is the snow cover sparse enough to permit photography of the salient features. Many months of preparation are required to plan the operation and prepare the equipment so that the short operating season may be used as efficiently as possible.

**PSC Applied Research Limited** has been acquired from the Hunting group of Canadian aviation companies by A. V. Roe Canada Limited. PSC Applied Research Limited employs an expanding staff of over 300 and operates two plants in Toronto's east end.

PSC Applied Research Limited becomes the sixth operating company in the A. V. Roe Canada group. The others are: Avro Aircraft Limited, Canadian Car and Foundry Company, Limited, Canadian Steel Foundries (1956) Limited, Canadian Steel Improvement Limited, Orenda Engines Limited. In addition, through CanCar, the group has controlling interest in Canadian General Transit Company Limited which is engaged in the leasing of railway tank cars.

In its six years' history, PSC Applied Research Limited has designed, engineered and produced a line of outstanding products. Probably the most widely known of its products is the R-Θ Computer which is now in quantity production for the RCAF.

In addition, it has designed and developed such equipment as: aerial survey cameras, radio-activity detectors, airborne magnetometers, airborne profile recorders, radar equipment and aerial navigation equipment, some of which was designed for the RCAF.

Much work has been done on various equipment for the air survey industry and for defence requirements. An automatic film processor and printer has filled a long-awaited need along with automatic control equipment for aircraft – ice detection and de-icing control systems; rocket-firing intervalometers and armament controls. Auroral recorders and station magnetometers, a sky camera and missile tracking cameras were developed for Canadian participation in the International Geophysical Year.

Miscellaneous devices include recording cameras with electrical programming control; camera intervalometers; positional and rate servo mechanisms; analog computers; the fabrication of microwave plumbing and all the production and test equipment for the company's major products.

Last year, the company opened the first privately-sponsored commercial environmental test laboratory in Canada.

**MEMBERSHIP OF THE C.A.I.**

as at the Meeting of the Council on the 25th February, 1957.

| | |
|---|---|
| **Technical** | **1829** |
| **Associates** | **77** |
| **Total** | **1906** |

The Technical grades comprise the following:

| | |
|---|---|
| Honorary Fellows | 11 |
| Fellows | 24 |
| Associate Fellows | 208 |
| Members | 938 |
| Technical Members | 490 |
| Technicians | 38 |
| Students | 120 |

# MEMBERS

## NEWS

**T. E. Stephenson, F.C.A.I.,** has been appointed to the Advisory Committee for the 1957 Institute of Radio Engineers Canadian Convention and Exposition.

**F. M. Hanna, A.F.C.A.I.,** has been chosen to lead the Photographic Survey Corporation's expedition to Foxe Inlet to continue the Government's Shoran-controlled survey of Canada's northlands. (*See page 140—Sec.*)

**A. E. Larratt, A.F.C.A.I.,** recently left Canadair Ltd. to take up an appointment of Chief Stress Design Engineer with The Kaman Aircraft Corporation, Conn.

**D. A. Newey, A.F.C.A.I.,** has been appointed Materials Manager of Bristol Aircraft (Western) Ltd.

**K. A. Austin, M.C.A.I.,** is now Senior Engineer with the Gas Turbine Department of Lycoming Division, Avco Corporation, having left Field Aviation.

**K. Blackburn, M.C.A.I.,** formerly with Dowty Equipment of Canada Ltd., is now employed by Can-Aero Consultants Ltd., as Chief Draftsman in their Special Machine Tool Design office.

**E. J. Carr, M.C.A.I.,** recently left Avro Aircraft Ltd. to take up a position as Design Engineer with Convair, San Diego.

**P. Y. Davoud, M.C.A.I.,** has been appointed Vice-President, Sales and Service, Orenda Engines Limited.

**G. Dietiker, M.C.A.I.,** has left the Engineering Dept. of Canadair Ltd. to accept a position in the Design office of the Boeing Airplane Co., Seattle.

**J. F. Haesslein, M.C.A.I.,** has resigned from his position at De Havilland Aircraft of Canada Ltd., to become Senior Design Engineer with the Lockheed Aircraft Corp., Georgia.

**E. L. Smith, M.C.A.I.,** is now employed by the Canadian Pratt & Whitney Aircraft Co., Ltd., having resigned from his position with the National Research Council.

**W. E. Corfield, Associate,** formerly with Weatherhead Co. of Canada, has taken up a position as Public Relations Manager with A. V. Roe Canada Ltd.

**V. Koby, Associate,** formerly editor of Canadian Aviation, has been appointed Assistant to the President of Spartan Air Services Ltd.

**W. J. Mann, Associate,** recently resigned from the Dept. of Defence Production to take up the post of Contracts Administrator with Curtiss-Wright of Canada Ltd.

**F. L. Trethewey, Associate,** has been named Assistant to the President and continues as a Director of Orenda Engines Ltd.

**L. B. Box, Technical Member,** has been posted to Douglas Aircraft Co., Santa Monica, as Canadair Representative.

## DEATH

It was learned with deep regret that **A/V/M E. W. Stedman, Hon.F.C.A.I.,** died in Ottawa on the 27th March. He was one of the most distinguished members of the Institute and served actively on the Education and Training Committee in 1955/56.

## ADMISSIONS

At a meeting of the Council, held on the 25th February, 1957, the following were admitted to the grades of membership shown.

### *Associate Fellow*

**E. J. Bobyn,** Superintendent G Wing, Canadian Armament Research and Development Establishment, P.O. Box 1427, Quebec, P.Q.

**F. R. Cordon** (on transfer from Member)

**W/C R. T. Hamilton,** Aeronautical Eng. Staff Officer, AFHQ, Ottawa, Ont.: *314 Kirchoffer Ave., Ottawa, Ont.*

**W. H. Jaworski,** Sr. Design Engineer, Avro Aircraft Ltd., Malton, Ont.: *15 Caswell Dr., Willowdale, P.O., Toronto, Ont.*

**W. M. Keddie,** Vice-President Engineering, Renfrew Aircraft & Engineering Ltd., Renfrew, Ont.: *99 Stevenson Cresc., Renfrew, Ont.*

**W/C P. de L. Markham** (on transfer from Member)

**L. C. McCarthy, Jr.,** Executive Assistant to Vice-President Engineering, Avro Aircraft Ltd., Malton, Ont.: *240 Oriole Parkway, Toronto, Ont.*

**D. H. Rogers** (on transfer from Member)

**D. N. Scard,** Flight Test Engineering Supervisor, Avro Aircraft Ltd., Box 4004, Terminal A, Toronto, Ont.

**T. A. Stenning,** Sr. Test Engineer, Avro Aircraft Ltd., Malton, Ont.: *8 Oakwood Ave., North, Apt. 10, Port Credit, Ont.*

**K. B. Young,** Met. Engr. Development & Research Div., International Nickel of Canada Ltd., 25 King St. West, Toronto, Ont.

### *Member*

**T. A. Batchelor,** Designer, Avro Aircraft Ltd., Malton, Ont.: *47 Riverhead Dr., Kipling Heights, Rexdale, Ont.*

**Dr. A. W. Bethune,** Chief Metallurgist, De Havilland Aircraft of Canada, Ltd., Postal Stn. L., Toronto, Ont.

**J. H. Blueth,** Group Leader Equipment, Canadair Ltd., Montreal, P.Q.: *5142 Patricia Ave., Montreal 29, P.Q.*

**E. J. Carr,** Aircraft Designer, Avro Aircraft Ltd., Malton, Ont.: *10 Toddbrook Dr., Thistletown P.O., Ont.*

**R. B. Cairns** (on transfer from Technical Member)

**R. S. Carslaw,** Group Leader Engineering, Canadair Ltd., Montreal, P.Q.: *158 Grenier St., St. Rose, P.Q.*

**E. A. Carter,** Vice-President and General Manager, Curtiss-Wright of Canada, Ltd., Rm. 540, 1980 Sherbrook St. W., Montreal, P.Q.

**M. Chesin,** Aircraft Supervisor, Bristol Aircraft (Western) Ltd., Winnipeg, Man.: *1205 Clifton Pl., Winnipeg 3, Man.*

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**F. H. Cressman,** Manager Aeronautical Div., B. F. Goodrich—Canada Ltd., 251 King St. West, Kitchener, Ont.

**J. Donovan,** Specialist Product Planning, Canadian General Electric Co., Ltd., 830 Lansdowne Ave., Toronto 4, Ont.

**F/S T. R. Drinkwater,** Air Maintenance Superintendent, RCAF Cold Lake, Alta.: *Box 1087, MPO 503, Grande Centre, Alta.*

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**G. Esilman,** Flight Test Engineer, Avro Aircraft Ltd., Malton, Ont.: *106 Elmhurst Dr., Rexdale, Ont.*

*Member* (Cont.)

**H. Fabiszewski,** Group Leader Electronic Section, Canadair Ltd., Montreal, P.Q.: *560 Tait St., Montreal 9, P.Q.*

**LCDR (P) W. H. Fearon,** Staff of DNA, RCN HQ, Ottawa, Ont.

**E. T. Fifield** (on transfer from Technical Member)

**J. E. Fox** (on transfer from Technical Member)

**J. R. Friesen,** Project Weights Estimator, Avro Aircraft Ltd., Malton, Ont.: *1514 Haig Blvd., Port Credit, Ont.*

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***Technical Member***

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**Sgt. D. P. L. Robbins,** NCO i/c Repair and Inspection Crew, MPO 503, Grande Centre, Alta.

**W. H. Simms,** Air Engineer, Spartan Air Services Ltd., Ottawa, Ont.: *190 Powell Ave., Apt. 5, Ottawa, Ont.*

**L. S. Styrczula,** Chief Draftsman, Trans-Canada Air Lines, Winnipeg, Man.: *832 Beaverbrook St., Winnipeg 9, Man.*

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**D. H. Whittaker,** Technical Illustrator, De Havilland Aircraft of Canada, Ltd., Downsview, Ont.: *C4 Kingscourt Apts., Ajax, Ont.*

**R. H. Yenney** (on transfer from Technician)

*Technician*

**A. Robinson,** Draftsman, Avro Aircraft Ltd., Malton, Ont.: *74 Cordella Ave., Mount Dennis, Toronto 9, Ont.*

*Student*

**J. B. Bradley,** Provincial Institute of Technology and Art, Calgary, Alta.: *1221 - 5th St. N.W., Calgary, Alta.*

**F/C J. M. Cooling,** Canadian Services College, Royal Roads, Victoria, B.C.

**F/C C. A. Crow,** Canadian Services College, Royal Roads, Victoria, B.C.

**Cadet R. J. G. A. Houston,** Canadian Services College, Royal Roads, Victoria, B.C.

**F/C F. C. Johnson,** Canadian Services College, Royal Roads, Victoria, B.C.

**Cadet J. B. Klassen,** Canadian Services College, Royal Roads, Victoria, B.C.

**Cadet R. J. Lawson,** Canadian Services College, Royal Roads, Victoria, B.C.

**Cadet K. A. McLean,** Canadian Services College, Royal Roads, Victoria, B.C.

**F/C J. C. McMeekin,** Canadian Services College, Royal Roads, Victoria, B.C.

**C. K. Meadley,** Dept. of Mechanical Engineering, Laval University, Quebec, P.Q.

**F/C D. H. Morrow,** Canadian Services College, Royal Roads, Victoria, B.C.

**F/C T. S. Neill,** Canadian Services College, Royal Roads, Victoria, B.C.

**F/C A. G. A. Pearson,** Canadian Services College, Royal Roads, Victoria, B.C.

**F. E. Roy,** University of Manitoba, Winnipeg, Man.: *235 Clare Ave., Winnipeg 13, Man.*

**Cadet P. Scholz,** Canadian Services College, Royal Roads, Victoria, B.C.

**J. S. Stevenson,** Sir George Williams College, Montreal, P.Q.: *Box 100, Hudson Heights, P.Q.*

**R. F. Trost,** University of Toronto, Toronto, Ont.: *223 Robert St., Toronto, Ont.*

**F/C K. Ujimoto,** Canadian Services College, Royal Roads, Victoria, B.C.

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*Associate*

**G/C A. M. Jardine,** Commanding Officer, RCAF Station, St. Hubert, P.Q.

**R. P. Purves,** Assistant Manager, Inter-Ocean Grain Co., Ltd., 704 Grain Exchange Bldg., Winnipeg 2, Man.

**A. A. Roberts,** Accounting Clerk, Trans-Canada Air Lines, Winnipeg, Man.: *280 Bonner Ave., R.R. No. 3, Winnipeg, Man.*

**D. L. Swail,** Public Relations, Northwest Industries Ltd., P.O. Box 517, Edmonton, Alta.

**W. J. Wienand, Jr.,** Vice-President i/c Aircraft Division, Enamel & Heating Products Ltd., Amherst, N.S.

# BOOKS

**Molecular Flow of Gases.** By G. N. Patterson. John Wiley and Sons, Inc., 1956. 217 pages. Illus. $7.50.

This book, which had its origin in a series of lectures given by the author to postgraduate students at the University of Toronto, was "written" to assist the reader in making a transition in outlook from the continuum to the molecular viewpoint.

After reviewing some of the basic concepts of the kinetic theory of gases, the author proceeds to derive, from suitable models of the molecular structure of a real gas, the relations linking the macroscale parameters, such as viscosity and temperature, which govern the flow of the corresponding macroscale models of the gas – that is, of such abstractions as the inviscid gas, the Newtonian fluid, and so on. He then uses the standard techniques of the mechanics of continua to investigate selected flow problems, seeking to demonstrate that the failure of a particular macroscale model to give results corresponding in every respect to those obtained experimentally with a real gas can be explained in terms of the difference between the molecular structure of the real gas and that of the molecular model employed. Both isentropic and non-isentropic flows of gases at normal densities are discussed.

In a final chapter, the author discusses the mechanics of highly-rarefied gases in two regimes; the slip flow regime, in which the density is low enough that discontinuities in pressure, temperature and velocity can exist at solid boundaries, though the gas is still viscous and heat-conducting, and the free-molecule flow regime, at very much lower densities, where the interaction between the molecules is of negligible importance.

The mathematical development, though condensed, does not exceed in difficulty the level required of most graduates in engineering physics and physics nowadays. The extensive bibliography will be of value to those who wish to pursue the subject in greater detail.

This book represents an attempt to provide a simple introduction to a very complex subject. As such, it should commend itself to all who, as a result of the current interest in very high speed flight at very high altitudes, must examine the validity of the continuum concepts on which aerodynamics has until lately been founded.

C. I. H. Nicholl

**Rotorcraft.** By R. N. Liptrot and J. D. Woods. Butterworth and Co. (Canada) Ltd., 1955. 172 pages. Illus. $6.40.

Essentially an introduction to the art of rotary-wing aircraft design, this is an exceedingly useful book. Falling into three sections, it first presents a tabulated historical review of rotorcraft development, followed by chapters on rotor theory, mechanical design, some aspects of control and stability and brief surveys of design procedure and economics, concluding with a sixty-page reference section containing technical data, illustrations of recent helicopters, and a comprehensive bibliography.

The inclusion of a chapter describing design features of a "typical" helicopter (actually the S-55), but with no photographs or drawings to illustrate the text, is puzzling. However, the treatment of performance theory is admirable. There is a brief but clear exposition of the fundamentals together with an indication of the corrections required to give greater accuracy. The latter permits the reader to appreciate the limitations of the theory, although the treatment is generally too cursory for practical use.

The discussion on the articulated rotor should clear up much of the confusion which exists on this subject, but the treatment of control and stability is regrettably brief. There are many photographs, but more diagrams would be desirable.

This book fills a serious gap in rotating-wing literature, providing within its 172 pages information that will satisfy most of the wants of a newcomer to the subject.

W. E. Robinson

**Elements of Gasdynamics.** By H. W. Liepmann and A. Roshko. John Wiley and Sons, Inc., 1957. 439 pages. Illus. $11.00.

About a decade ago, the rapid advent of high-speed flight left a void in the understanding of the phenomena associated with compressible flows. At that time a very timely and important book appeared called, "Introduction to Aerodynamics of a Compressible Fluid," by H. W. Liepmann and A. E. Puckett. This volume helped numerous aeronautical engineers and scientists to bridge the gap between the relatively well developed field of subsonic aerodynamics and the unknown fields of transonic and supersonic flows.

Although the ten years which have passed have been marked by a considerable understanding of these problems, many new ones have presented themselves, especially in the realm of hypersonic flight. The aerodynamicist is becoming increasingly aware that not only must he know a great deal about gas dynamics but that molecular physics and certain spheres of chemistry now have become his working tools. Once again the important new book by Professor H. W. Liepmann and Professor A. Roshko gives a physical insight into these phenomena and consolidates the advances of the past ten years. This volume will undoubtedly be of considerable assistance to all those working in the field of aeronautics in appreciating the significance of present day aerodynamical problems.

The book consists of the following 14 chapters: concepts from thermodynamics, one-dimensional gas dynamics, one-dimensional wave motion, waves in supersonic flow, flow in ducts and wind tunnels, methods of measurement, the equations of frictionless flow, small-perturbation theory, bodies of revolution-slender body theory, the similarity rules of high-speed flow, transonic flow, the method of characteristics, effects of viscosity and conductivity, concepts from gas kinetics. The text is very readable. It is set in fine type on good paper and is well illustrated with informative graphs, figures and photographs.

This is an excellent book and is recommended highly to aeronautical engineers and scientists.

I. I. Glass

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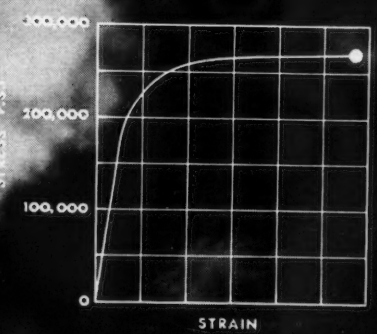


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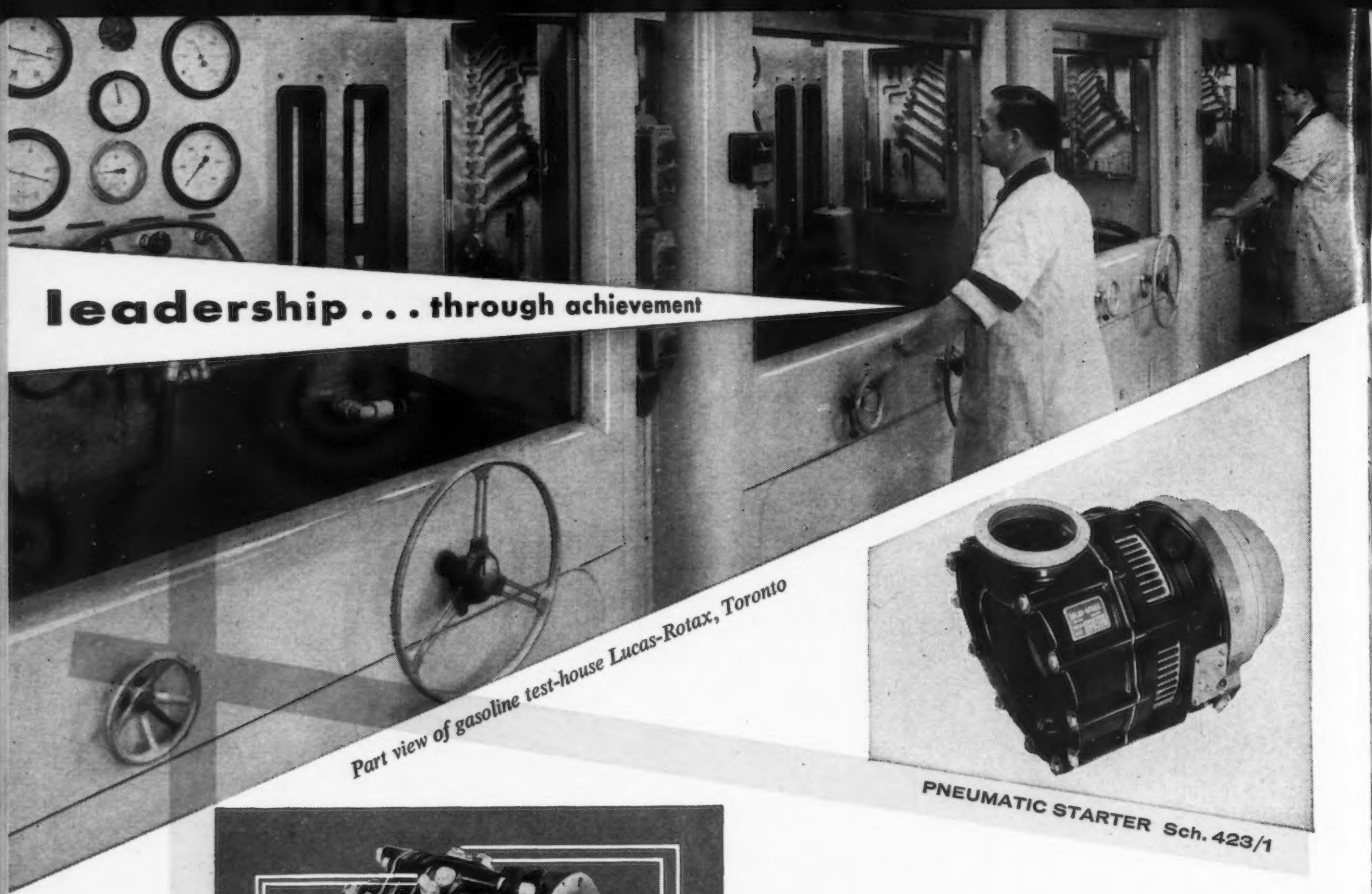

*Part view of gasoline test-house Lucas-Rotax, Toronto*



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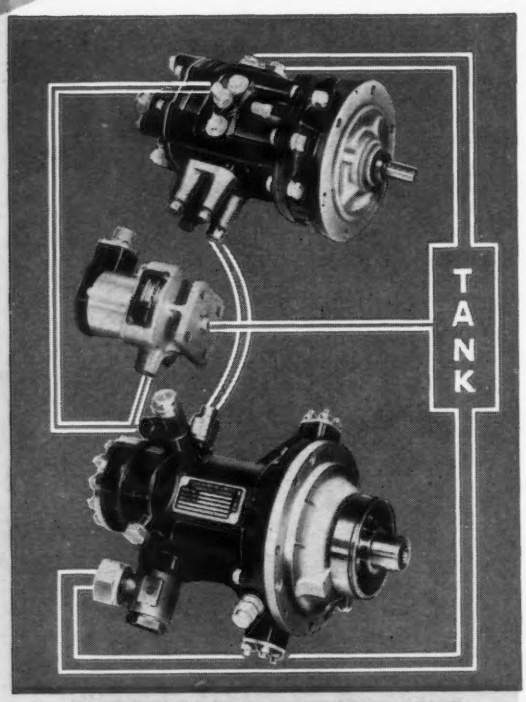


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